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The Roaring Thirties

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Chapter 1

The Roaring Thirties

When people think of the United States in the 1930s, they rarely imagine a time of technological and organizational innovation, much less of rapid labor productivity growth. Instead, this decade is more often associated with lengthy unemployment lines, dust storms, crop failure, foreclosures and overall financial malaise. Contemporaries felt no differently. In the early 1940s, *Life* magazine labeled the previous decade the "Gloomy Thirties," whereas *Time* opted for the, equally grim, "Threadbare Thirties."[1]

In academics, the 'Great Crash' of 1929 and the 'Great Depression' that ensued have also left their mark and a great body of literature has been written on the subject. Most of these studies, both in economics and economic history, deal with the stock-market crash, the bank-runs and the international monetary crisis.[2] Many evaluate the direct consequences on consumer demand, employment, price levels, international trade and real output.[3] Moreover, in light of the recent financial crisis, various studies reflect on the lessons learned from the 1930s by reexamining the fiscal and monetary policies

1. M. Meredith, "The 'Nifty Fifties,' the 'Flying Forties,' the 'Threadbare Thirties,' and the 'Roaring Twenties' of Twentieth Century America," *American Speech* 26 (1951): 228.

2. B. Bernanke, *Essays on the Great Depression* (Princeton: Princeton University Press, 2000); B. Eichengreen, *Golden Fetters: The Gold Standard and the Great Depression, 1919–1939* (New York: Oxford University Press, 1992); M. Friedman and A. Schwartz, *A Monetary History of the United States, 1867–1960* (Princeton: Princeton University Press, 1963); L. Chandler, *America's Greatest Depression, 1929–1941* (New York: Harper & Row, 1970); E. White, "The Stock Market Boom and Crash of 1929 Revisited," *Journal of Economic Perspectives* 4 (1990): 67–83.

3. B. Bernanke, "Non-monetary Effects of the Financial Crisis in the Propagation of the Great Depression," *American Economic Review* 73 (1983): 257–76; H. Cole and L. Ohanian, "The Great Depression in the United States from a Neoclassical Perspective," *Federal Reserve Bank of Minneapolis Quarterly Review* 23 (1999): 2–24; T. Hatton and M. Thomas, "Labour Markets in the Interwar Period and Economic Recovery in the UK and the USA," *Oxford Review of Economic Policy* 26 (2010): 463–85; C. Romer, "The Great Crash and the Onset of the Great Depression," *Quarterly Journal of Economics* 105 (1990): 597–624; P. Temin and B. Wigmore, "The End of One Big Deflation," *Explorations in Economic History* 27 (1990): 483–502.

implemented by the Hoover and Roosevelt administrations.[4]

Where most of these academic contributions focused on the output not produced, income not earned and resources not exploited, the economic historian Alexander Field argues that the 1930s were actually the "most technologically progressive decade of the century."[5] Field's hypothesis builds upon earlier work by Michael Bernstein and Ester Fano and entails two main claims: firstly, "during this period businesses and government contractors implemented or adopted on a more widespread basis a wide range of new technologies and practices, resulting in the highest rate of peak-to-peak [total-]factor productivity growth in the century, and secondly, that the depression years produced advances that replenished and expanded the larder of unexploited or only partially exploited techniques, thus providing the basis for much of the labor and [total-]factor productivity improvement of the 1950s and 1960s."[6]

The period 1929–1941, Field shows, witnessed little to no growth in both labor hours and capital for the US private non-farm economy.[7] Nevertheless, the output of this sector was 33 to 40 percent higher in 1941 as compared with 1929. This gap between the growth of output and inputs reflected improvements in total-factor productivity (TFP) or disembodied technological change, which Fields put somewhere between 2.3 and 2.8 percent per annum over this twelve-year period. These gains in TFP represented, according to Field, real improvements in the productive capacity of the American economy.[8] This view contrasts sharply with the predictions of real business cycle theory, which maintains that deviations in TFP from trend are *cause* not consequence of business cycles.[9] Recently, however, Field's claims have been endorsed by a study by Robert Inklaar, Herman de Jong and Reitze Gouma, who show that technology change in the interwar era was not positively correlated with input us-

4. N. Crafts and P. Fearon, "Lessons from the 1930s Great Depression," *Oxford Review of Economic Policy* 23 (2010): 1–56; C. Romer, "Lessons from the Great Depression for Policy Today," *Teach-In on the Great Depression and World War II: University of Oklahoma* 1 (2013): 1–25; A. Shlaes, *The Forgotten Man: A New History of the Great Depression* (New York: HarperCollins Publishers, 2007); P. Temin, *Lessons from the Great Depression* (Cambridge: MIT Press, 1989).

5. A. Field, "The Most Technologically Progressive Decade of the Century," *American Economic Review* 93 (2003): 1399–1413.

6. Field, "The Most Technologically Progressive Decade of the Century," 1399; M. Bernstein, *The Great Depression. Delayed Recovery and Economic Change in America, 1929–1939* (Cambridge: Cambridge University Press, 1987); M. Bernstein, "The Response of American Manufacturing Industries to the Great Depression," *History and Technology* 3 (1987): 225–248; E. Fano, "Technical Progress as a Destabilizing Factor and as an Agent of Recovery in the United States Between the Two World Wars," *History and Technology* 3 (1987): 249–74.

7. A. Field, *A Great Leap Forward: 1930s depression and U.S. economic growth* (New Haven: Yale University Press, 2011), 7.

8. A. Field, "The Procyclical Behavior of Total Factor Productivity in the United States, 1890–2004," *Journal of Economic History* 70 (2010): 347.

9. Cole and Ohanian, "The Great Depression in the United States from a Neoclassical Perspective."

age.[10] Hence, these authors demonstrate, “there was little role for technology shocks in driving the Great Depression.”[11] The technological gains thus indeed represent a very substantial and real increase in potential output, exceeding those attained in the 1920s or even in the ‘Golden Age’, the quarter century between 1948 and 1973.

For specific examples of the largely disembodied technical change during the depression years Field turns to a contemporary study by David Weintraub.[12] Weintraub describes the development of chrome-plating and corrosion-resistant steel alloys as well as improvements in paints, varnishes and lacquers. He showed that by 1939, “the development of cellulose lacquers, for instance, has cut down the time required to finish a motor car (through reducing the drying time) from twenty-six days to a few hours.”[13] Further advances in chemicals resulted in improved yields from ore mining and new commercial uses of waste-products, preeminently in the petroleum and natural gas industries.[14] As noted by Field, “finding commercial uses for waste was [...] about as close to manna from heaven as one could get.”[15]

In addition, the 1930s observed a general increase in the utilization of large-capacity equipment, greatly boosting both labor- and capital productivity. This was evident for equipment in general use such as industrial locomotives, power shovels and electric motors as well as fixed installations like cement kilns, milling equipment in mining, conveyors in flour mills and electric-power-generating units.[16] The use of, for instance, larger boilers in the electric-power-generating industry led to greater thermal efficiency and an almost uninterrupted rise in the kilowatt-hours of energy distributed throughout the 1920s and 1930s.[17] Closely associated with this continued trend toward larger units was the growing importance of industrial measuring and controlling devices. These improvements greatly facilitated automatic process control, reduced downtime and maintenance costs and lengthened the life of equipment considerably.[18]

The depression years also witnessed the introduction of new and improved materials and parts. In addition to the previously mentioned steel alloys, manufactures

10. R. Inklaar, H. de Jong, and R. Gouma, “Did Technology Shocks Drive the Great Depression? Explaining Cyclical Productivity Movements in U.S. Manufacturing, 1919–1939,” *Journal of Economic History* 71 (2011): 827–858.

11. Ibid., 851.

12. D. Weintraub, “Effects of Current and Prospective Technological Developments Upon Capital Formation,” *American Economic Review* 29 (1939): 15–32.

13. Ibid., 23.

14. Weintraub, “Effects of Current and Prospective Technological Developments,” 23, 28; Bernstein, “The Response of American Manufacturing Industries to the Great Depression,” 238–42.

15. Field, *A Great Leap Forward*, 49.

16. Weintraub, “Effects of Current and Prospective Technological Developments,” 17.

17. Field, *A Great Leap Forward*, 48; J. Kendrick, *Productivity Trends in the United States* (Princeton: National Bureau Economic Research, 1961), 590.

18. Weintraub, “Effects of Current and Prospective Technological Developments,” 19.

increasingly substituted plastics for wooden or metal parts, developed new materials for cutting tools (e.g. tungsten carbide) and replaced outdated friction bearings for roller bearings on a great part of the rotating machinery installed since 1930.[19] Finally, the 1930s saw further improvements in plant layout and management through the installation of conveyer belts and the implementation of continuous-flow production, amongst others. Although the foundation for many of these advances had been laid in the 1920s, there were still substantial gains to be reaped during the depression era.[20]

Field's finding that the 1930s was indeed technologically a very progressive decade raises a number of new questions, however. Although Field speculates that the productivity gap between Europe and the US widened further during the 1930s, he does not come forward with comparative evidence.[21] His account is centered almost entirely around the American experience, begging the question whether these rapid technological developments were unique to the US or if similar developments were apparent in Europe as well. In addition, Field plays down the role of human capital. As illustrated by Claudia Goldin and Lawrence Katz, the American labor force experienced an unprecedented increase in educational attainment during the late nineteenth and early twentieth century, a trend that continued unchallenged throughout the depression era.[22] Surprisingly though, Field claims that "the effect of labor quality improvement on growth in output per hour or TFP growth over the entire period 1929–1941 was dwarfed by other factors."[23]

This study reexamines the comparative labor-productivity performance of the United States as well as the United Kingdom – the main industrial-rival of the US. In light of the dynamic productivity developments reported by Field, I reassess the British technological and organizational innovations and provide a novel explanation for the rapid divergence of the Anglo-American labor-productivity levels, observed during the early twentieth century. Chapters 2 and 3 present new benchmarks of Anglo-American comparative labor productivity, establishing the relative productivity gap between the two leading industrial nations at both the start of the twentieth century (ca. 1910) as well as the interwar era (1935). Chapter 4 discusses technological change, capital accumulation and efficiency decline in Britain and the US between the wars. Lastly, chapter 5

19. Weintraub, "Effects of Current and Prospective Technological Developments," 21–2.
20. Field, *A Great Leap Forward*, 49.
21. A. Field, "The Equipment Hypothesis and US Economic Growth," *Explorations in Economic History* 44 (2007): 49.
22. C. Goldin and L. Katz, *The Race Between Education and Technology* (Cambridge: Belknap Press of Harvard University Press, 2008).
23. Field, *A Great Leap Forward*, 37–8.

reexamines American labor quality for the first half of the twentieth century.

I find that, on the eve of the First World War, the Anglo-American aggregate income and productivity gap was greater than suggested by previous estimates.[24] In chapter 2, I show that particularly the American agriculture, mining and manufacturing sectors demonstrated a strong performance in comparison to their British counterparts. Around 1910, value added per hour worked in US manufacturing, for instance, was a little over twice as high as it had been in the UK. Regardless of this substantial lead, the American manufacturing sector forged even further ahead during the 1920s and 1930s, widening the productivity gap to almost 280 percent in 1935; as I demonstrate in chapter 3. Strikingly, I do not find any evidence for a 'temporary cyclical narrowing' prior to the Second World War, as suggested by Stephen Broadberry.[25] On the contrary, when I adjust labor input for hours worked, the productivity gap observes a continued upward trend throughout the depression years. The steady divergence of the Anglo-American labor-productivity levels in manufacturing corroborates Field's claim of major productivity improvements in the US during the 1930s.

America's lead over Europe in manufacturing productivity from the late nineteenth century onwards has often been contributed to differences in initial conditions, trapping Europe in a relatively declining, labor-intensive and low-productive technological path.[26] Likewise, Broadberry argues that the lack of productivity convergence reflected the persistence of distinct industrial technologies in Britain and the United States.[27] British producers continued to pursue a crafts-based production system, losing both productivity and technological leadership to the American system of mass-production that, up to the 1970s, proved to be technologically more progressive.

In chapter 4, I reassess the productivity dynamics in British manufacturing during the early twentieth century on the basis of a novel analytical framework by Susanto Basu and David Weil that emphasizes the role of learning and localized technical change and which predicts convergence in light of rapid capital deepening.[28] By means of a data envelopment analysis (DEA), I assess the effects of capital accumulation, technological change, and efficiency change on British and American labor-productivity growth.[29] I find evidence for a considerable increase in the capital-

24. S. Broadberry and D. Irwin, "Labor Productivity in the United States and the United Kingdom During the Nineteenth Century," *Explorations in Economic History* 43 (2006): 257–279.

25. S. Broadberry, *The Productivity Race: British Manufacturing in International Perspective, 1850–1990* (Cambridge: Cambridge University Press, 1997), 291.

26. P. David, *Technical Choice, Innovation and Economic Growth. Essays on American and British Experience in the Nineteenth Century* (Cambridge: Cambridge University Press, 1975), 66.

27. S. Broadberry, "Technological Leadership and Productivity Leadership in Manufacturing Since the Industrial Revolution: Implications for the Convergence Debate," *Economic Journal* 104 (1994): 291–302.

28. S. Basu and D. Weil, "Appropriate Technology and Growth," *Quarterly Journal of Economics* 113 (1998): 1025–1054.

29. S. Kumar and R. Russell, "Technological Change, Technological Catch-up, and Capital Deepening: Relative Contributions to Growth and Convergence," *American Economic Review* 92 (2002): 527–548.

intensity levels within British manufacturing (proxied by statistics on the horsepower rating of power equipment), particularly in the 'new' industries closely associated with the Second Industrial Revolution. Manufactures in these key industries – i.e. transportation equipment, printing, chemicals, petroleum and rubber – actively began to adopt modern techniques of mass-production and managerial control.[30] Even though by 1930 British capital intensity levels still trailed the United States by almost two decades, overall dissimilarities between best-practice production techniques used in American and British manufacturing industries disappeared to a large extent.[31] British producers of motor vehicles, for instance, were following the path set out by the American vehicle industry. The interwar era witnessed large investment programs, with the gradual introduction of mechanized production techniques, assembly lines and specialized machinery used to produce individual items on a continuous basis.[32] As illustrated by Barry Eichengreen, by the end of the 1930s management in a vast number of manufacturing industries was being professionalized, spending on research and development had tripled over the course of the decade and new products and processes proliferated.[33]

As demonstrated by the steady divergence of the Anglo-American labor-productivity levels during the early twentieth century, this process of capital deepening was not accompanied by an immediate labor-productivity increase in British manufacturing. Regardsless, in contrast to existing literature, I do not interpret the lack of catch-up growth during the 1920s and 1930s as a failure on the part of British entrepreneurs.[34] Instead, I suggest a sequence where first opportunities for growth are created followed by a period of learning-by-doing and actual productivity catch-up.[35] The initial phase of catch-up, the adoption of new production techniques through the accumulation of capital, involves an extensive transformation of the production process. This causes efficiency levels to deteriorate in the short run. Only after the economy has successfully adjusted to the new state and has 'learned' to operate the new technology at its full potential, can the labor-productivity gap to the frontier be

30. H. Richardson, "The New Industries Between the Wars," *Oxford Economic Papers* 13 (1961): 360–384; H. Richardson, "The Basis of Economic Recovery in the Nineteen-Thirties: A Review and a New Interpretation," *Economic History Review* 15 (1962): 344–363.

31. W. Salter, *Productivity and Technical Change*, 2nd ed. (Cambridge: Cambridge University Press, 1966), 72–3.

32. S. Bowden and D. Higgins, "British Industry in the Interwar Years," chap. 14 in *The Cambridge Economic History of Modern Britain*, ed. R. Floud and P. Johnson, vol. 2 (Cambridge: Cambridge University Press, 2004), 386–7.

33. B. Eichengreen, "The British Economy Between the Wars," chap. 12 in Floud and Johnson, *The Cambridge Economic History of Modern Britain*, 2:341.

34. Broadberry, "Technological Leadership and Productivity Leadership in Manufacturing," 292; D. Greasley and L. Oxley, "Comparing British and American Economic and Industrial Performance 1860–1993: A Time Series Perspective," *Explorations in Economic History* 35 (1998): 184.

35. M. Timmer and B. Los, "Localized Innovation and Productivity Growth in Asia: An Intertemporal DEA Approach," *Journal of Productivity Analysis* 23 (2005): 58, 60.

narrowed. In line with Field's argument for the US, I argue that the advances made during the depression years provided the basis for much of the labor and total-factor productivity growth of British industry during the Golden Age. I do argue that, in the case of Britain, the modernization process was curtailed by institutional rigidities, which explains why technological diffusion was not as widespread and the convergence of technological paths following the Second World War did not occur as quickly as observed in the case of, for instance, West-Germany and France.[36] Still, the British shift toward mass-production techniques during the interwar era provides a strong case for a remarkable escape from the labor-intensive path, challenging the traditional technological lock-in hypothesis.

In chapter 5, I turn to the American advances in education attainment and its effects on the countries' productivity potential. As shown by Goldin and Katz, the Americans had a strong tradition of educating their youth at public charge.[37] The American approach to schooling stood in stark contrast to the European system, which was still reserved for the relatively rich. By 1930, compared to Britain, the US was already three to four decades ahead in post-elementary education; a lead which remained large well into the second half of the twentieth century.[38] The advances in schooling during the early twentieth century transformed the American workforce and prepared the American youth for a wide array of potential tasks and occupations, allowing them to adequately respond to the considerable technological change that marked this period.[39] Various authors have claimed that America's approach to schooling was one of the driving forces behind its technological dynamism and paved the way for rapid economic growth.[40] Nonetheless, as previously noted, Field ascribes only a minor role to the advances in education (or the 'quality' of labor in general) on labor and total-factor productivity growth during the years between 1929 and 1941.[41]

In order to fully assess the impact of the substantial investments in schooling on the American economy, I turn to an approach developed by Dale Jorgenson and Zvi

36. B. van Ark, *International Comparisons of Output and Productivity: Manufacturing Productivity Performance of Ten Countries from 1950 to 1990* (Groningen: Groningen Growth & Development Centre, 1993), 86–7; N. Crafts and T. Mills, "TFP Growth in British and German Manufacturing, 1950–1996," *Economic Journal* 115 (2005): 650; N. Crafts, "British Relative Economic Decline Revisited: The Role of Competition," *Explorations in Economic History* 49 (2012): 22–3.

37. Goldin and Katz, *The Race Between Education and Technology*, 12.

38. C. Goldin, "The Human-Capital Century and American Leadership: Virtues of the Past," *Journal of Economic History* 61 (2001): 267.

39. Goldin and Katz, *The Race Between Education and Technology*, 29.

40. E. Denison, *The Sources of Economic Growth in the United States and the Alternatives Before Us* (New York: Committee for Economic Development, 1962), 73; Goldin and Katz, *The Race Between Education and Technology*, 12.

41. Field, *A Great Leap Forward*, 37–8.

Griliches.[42] The key innovations in their work was to adjust the traditional measure of labor input for improvements in quality. The main principle behind the labor quality adjustment is the distinction among several different types of labor inputs (e.g. educational attainment, experience, etc.) characterized by one or more quantifiable factors that affect the productivity potential of the average worker. By assigning weights to these categories, one can measure the change in the productivity 'potential' of the workforce. When this new measure of labor input is used in a growth accounting framework – instead of a raw input measure such as the number of employees or hours worked – output growth as a result of better educated and trained workers are ascribed to the growth of inputs, rather than productivity or technology growth.[43]

In contrast to previous studies, my estimates include a detailed sectoral breakdown. This allows me to study the development of labor quality for both the US labor force as a whole, as well as the change across individual sectors and industries. I find that labor quality exhibited a steady increase in the decades between 1900 and 1950. The average growth during this period was just over 0.7 percent per annum which, by comparison to both more recent decades as well as the development of human capital in other countries was quite rapid.[44] This growth resulted primarily from a general shift of employment from the low-productive agricultural sector to high-productive sectors (e.g. finance, professional services, etc.) in conjunction with a general rise in the educational attainment of the workforce. At the sectoral level, my new estimates show some notable variations in the rates of growth. Overall, labor quality change was much more pronounced in agriculture and industry than it was for the service sector, stressing the need for a disaggregate analysis when studying human capital and its effects on productivity change.

These new estimates closely agree with the continuous increase in the average years of schooling observed by Goldin and Katz.[45] Consequently, I conclude that Field's claim that the change in labor-quality during the depression years played only a minor role in the rapid growth of output per hour and TFP does not stand up under scrutiny. He based his calculations on the work of John Kendrick, who estimated an average rate of growth for the 1900–1950 period half as large as even my most conservative estimates.[46] Most importantly, however, Kendrick claims there was little to no growth in labor quality between 1920 and 1940, whereas my figures indicate a contin-

42. Z. Griliches, "The Sources of Measured Productivity Growth: United States Agriculture, 1940–60," *Journal of Political Economy* 71 (1963): 340; D. Jorgenson and Z. Griliches, "The Explanation of Productivity Change," *Review of Economic Studies* 34 (1967): 249–283.

43. D. Jorgenson, M. Ho, and K. Stiroh, "A Retrospective Look at the U.S. Productivity Growth Resurgence," *Journal of Economic Perspectives* 22 (2008): 3–24.

44. E. Denison and J. Poullier, *Why Growth Rates Differ: Postwar Experience in Nine Western Countries* (Washington D.C.: Brookings Institution Press, 1967); Goldin and Katz, *The Race Between Education and Technology*.

45. Goldin and Katz, *The Race Between Education and Technology*.

46. Kendrick, *Productivity trends in the United States*, 32–4.

uous and strong growth throughout the interwar era. Regardless of the considerable growth in labor quality for most sectors of the American economy, the improvements in human capital cannot account for all of the technological growth observed in chapter 4, however. My estimates do highlight that the American labor force continued to improve rapidly during the depression years, preparing her for the technological and organizational innovations characterizing this decade.

Overall, the 1930s – though scarred by relentless unemployment, mass migration and profound social and cultural change – were far from gloomy in terms of technological and business innovation. The advances in products and materials, improvements in plant layout, management and human capital, and the emergence of new production techniques placed both the American and the British economy in a position to embark on a new pattern of growth and development. In light of this, the *Time's* epithet of "Threadbare Thirties" does not really do the 1930s justice. The "Roaring Thirties" is a label more befitting the great technological advances and the extensive modernization that marked this tumultuous decade – perhaps even more so than the 1920s, the decade commonly affiliated with this adjective.[47]

47. The title of this study is actually based on the title of David Henderson's book review of *A Great Leap Forward*, which he was so kind to let me borrow. See, D. Henderson, "The Roaring Thirties," *Policy Review* 169 (2011): 91–96.

Chapter 2

Taking Over

A New US/UK Productivity Benchmark and the Nature of American Economic Leadership ca. 1910*

2.1 Introduction

From the 1940s onwards such notable economists as Simon Kuznets and Brian Mitchell in the US and Colin Clark in the UK have been active in the field of comparative economic performance of nations.[1] At present the best known comparisons of long-run productivity performance come from the seminal work of Angus Maddison.[2] Part of the appeal of his approach is the wide temporal and spatial coverage of his data, the transparent methodology and his sole reliance on national time-series published by statistical offices, which makes it exceptionally well suited for research on comparative economic growth.

The Maddison time-series, or any of the long-term studies on economic growth for that matter, suffer from at least one major drawback: time-series projections do not adequately account for shifts in sectoral output and changes in product prices. This becomes particularly apparent when time-series of different origins are projected from a

*. Parts of this chapter have previously been published in E. Frankema, P. Woltjer, and J. Smits, "Changing Economic Leadership: A New Benchmark of Sector Productivity in the United States and Western Europe, ca. 1910," *Tijdschrift voor Sociale en Economische Geschiedenis* 10 (2013).

1. S. Kuznets, *Modern Economic Growth: Rate, Structure and Spread* (Yale: Yale University Press, 1966); B. Mitchell, *International Historical Statistics. Europe 1750–2005*, 6th ed. (Basingstoke: Palgrave Macmillan, 2007); C. Clark, *The Conditions of Economic Progress*, 2nd (London: MacMillan, 1951).

2. A. Maddison, *Phases of Capitalist Development* (Oxford: Oxford University Press, 1982); A. Maddison, *Dynamic Forces in Capitalist Development* (Oxford: Oxford University Press, 1991); A. Maddison, *Monitoring the World Economy 1820–1992* (Paris: Organisation for Economic Cooperation & Development, 1995); A. Maddison, *The World Economy: A Millennial Perspective* (Paris: Organisation for Economic Cooperation & Development, 2001).

certain benchmark-year into distant periods. In recent years, economic historians have stressed the need for new, more detailed, comparisons of welfare and productivity for earlier periods, particularly for the pre-World War I era.[3]

As the debate between Broadberry versus Ward and Devereux in the *Journal of Economic History* has emphasized, direct benchmark comparisons between countries are a much wanted alternative for the long-span projections.[4] In this discussion, Marianne Ward and John Devereux challenge the conventional picture of relative income levels and the timing of the American take-over in particular. The consensus view of US/UK relative income is based almost exclusively on the work of Maddison.[5] Maddison's extrapolations shows that income levels in the United Kingdom exceeded that of the United States by approximately one-third in 1870. As illustrated in the second column of table 2.1, Maddison's time-series evidence reveals that, from 1870 onwards, the Anglo-American income gap declined until, sometime around the turn of the century, the US definitively took over the lead. These projections all hinge on an income benchmark for the year 1990, which Maddison extrapolates backwards to the late nineteenth century, relying on a collection of well over 100 years worth of national accounts to bridge the gap. Economists have cast severe doubts, however, whether these long-span projections are actually viable and produce credible results in the face of two World Wars, several major depressions, and the host of new products and services introduced over the course of the twentieth century.[6]

Ward and Devereux provide an alternative measure of the US/UK income relatives based on direct Purchasing-Power-Parity (PPP) adjusted benchmarks of expenditure.[7] For the period between 1872 to 1930, Ward and Devereux constructed seven Anglo-American expenditure benchmarks, which they supplemented with existing benchmarks from Gilbert and Kravis and the work done under the auspices of the Interna-

3. L. Prados de la Escosura, "International Comparisons of Real Product, 1820–1990," *Explorations in Economic History* 37 (2000): 1–41; K. Fukao, D. Ma, and T. Yuan, "Real GDP in Pre-war Asia: A 1934–36 Benchmark Purchasing Power Parity Comparison with the U.S.," *Review of Income and Wealth* 53 (2007): 503–537; J. van Zanden, "Rich and Poor Before the Industrial Revolution: A Comparison Between Java and the Netherlands at the Beginning of the Nineteenth Century," *Explorations in Economic History* 40 (2003): 1–23.

4. M. Ward and J. Devereux, "Measuring British Decline: Direct Versus Long-Span Income Measures," *Journal of Economic History* 63 (2003): 826–851; S. Broadberry, "Relative Per Capita Income Levels in the United Kingdom and the United States since 1870: Reconciling Time-Series Projections and Direct-Benchmark Estimates," *Journal of Economic History* 63 (2003): 852–863; M. Ward and J. Devereux, "Relative U.K./U.S. Output Reconsidered: A Reply to Professor Broadberry," *Journal of Economic History* 64 (2004): 879–891.

5. Maddison, *The World Economy*.

6. See Prados de la Escosura, "International Comparisons of Real Product" for a discussion.

7. Ward and Devereux, "Measuring British Decline."

Table 2.1: Comparative GDP per capita, US and UK (UK=100, 1872–1990)

year	*Ward & Devereux*	*Maddison*	*year*	*Ward & Devereux*	*Maddison*
1872	118	78	1955	217	143
1874	118	79	1967	175	147
1878	127	84	1970	167	143
1884	130	87	1973	169	143
1891	122	90	1975	156	141
1905	122	105	1980	154	147
1930	133	118	1985	167	152
1950	208	143	1990	145	145

Source: M. Ward and J. Devereux, "Measuring British Decline: Direct Versus Long-Span Income Measures," *Journal of Economic History* 63 (2003): 840; A. Maddison, "Historical Statistics of the World Economy, 1–2008 AD," Groningen Growth & Development Centre, 2008, accessed on 11 March 2011.

tional Comparison Project.[8] In all they provide sixteen 'snapshots' which renders a complete overview of relative US/UK performance over the course of the long twentieth century (see table 2.1). From this Ward and Devereux conclude that – contrary to the estimates by Maddison – the US, not the UK, led in terms of income per capita in the 1870s. "The UK kept pace with the US throughout the late Victorian era, while most of the British relative decline occurred between 1905 and 1950."[9]

The findings by Ward and Devereux met with harsh criticism from Broadberry, who disputed their direct benchmarks on account of the implied revision of the relative US/UK price levels as well as their handling of the historical national accounts.[10] Mostly though, Broadberry deplored the fact that no attempt was made toward a reconciliation of the long-span time-series projections and the direct benchmarks. He states that, "a satisfactory account of the evolution of relative per capita incomes over a long period should be able to encompass both sorts of evidence."[11] As a check against the time-series extrapolations, Broadberry proposes a set of sectoral productivity benchmarks, for which he suggests basing the benchmark estimate of relative Gross Domestic Product (GDP) on output as opposed to the expenditure approach taken by Ward and Devereux.

8. M. Gilbert and I. Kravis, *An International Comparison of National Products and the Purchasing Power of Currencies* (Paris: The Organisation for European Economic Cooperation, 1954); M. Gilbert, *Comparative National Products and Price Levels* (Paris: The Organisation for European Economic Cooperation, 1958); Maddison, *Monitoring the World Economy*.

9. Ward and Devereux, "Measuring British Decline," 826.

10. Broadberry, "Relative Per Capita Income Levels."

11. ibid., 852.

To this aim, Broadberry and Douglas Irwin presented a comprehensive Anglo-American industry-of-origin benchmark for the year 1910.[12] This industry-of-origin benchmark – based primarily on earlier work by Broadberry – provides a full breakdown of the relative productivity and income differentials between the US and the UK at the sectoral level.[13] Broadberry and Irwin conclude that their benchmark estimate of both GDP per capita and per worker move closely in line with the time-series projections.[14] They trace the source of the initial British lead in GDP per capita to a slightly higher level of labor productivity in the UK coupled with a substantially higher share of the British population in the labor force. The latter greatly boosted overall British output per capita.

In their sectoral decomposition of labor productivity, Broadberry and Irwin show that "the United States had roughly equal labor productivity in agriculture, much higher productivity in industry, and a rapid catch-up in service sector productivity."[15] The UK, already by 1870, engaged a large share of its labor force in industry and services, while US labor was still primarily engaged in the low-productive agricultural sector. The initial British aggregate labor-productivity lead was thus the result of compositional effects rather than superior productivity at the sectoral level. On the basis of this evidence, Broadberry claims that the US take-over, both in terms of overall productivity and per capita income, was the result of a structural shift away from agriculture together with rapid relative productivity increases in the American service sector.[16] The close correspondence between the evidence presented by Broadberry and Irwin and the Maddison projections, led the former to suggest that the conventional view is indeed correct. Consequently, they reject the claim by Ward and Devereux, as well as Leandro Prados de la Escosura, that index number problems introduce a considerable bias in the long-span Anglo-American projections.[17]

Recent literature emphasizes, however, that comparative productivity in manufacturing was more dynamic than asserted by Broadberry and that technological developments in this sector played a substantial role in explaining the productivity gap be-

12. Broadberry and Irwin, "Labor Productivity in the United States and the United Kingdom."

13. S. Broadberry, "Comparative Productivity in British and American Manufacturing During the Nineteenth Century," *Explorations in Economic History* 31 (1994): 521–548; Broadberry, *The Productivity Race*; S. Broadberry, "Forging Ahead, Falling Behind and Cathing-Up: A Sectoral Analysis of Anglo-American Productivity Differences, 1870-1990," *Research in Economic History* 17 (1997): 1–37; S. Broadberry, "How Did the United States and Germany Overtake Britain? A Sectoral Analysis of Comparative Productivity Levels, 1870-1990," *Journal of Economic History* 58 (1998): 375–407.

14. Broadberry and Irwin, "Labor Productivity in the United States and the United Kingdom," 273.

15. ibid., 262.

16. Broadberry, *The Productivity Race*; Broadberry, "How Did the United States and Germany Overtake Britain?"

17. Prados de la Escosura, "International Comparisons of Real Product"; Ward and Devereux, "Measuring British Decline."

tween the US and UK for the inter-war era.[18] In addition, it appears unlikely that the American agricultural sector was left entirely unaffected by the rapid developments in industry during the late nineteenth and early twentieth century. Given the strong increase in demand for agricultural goods (in particular from the textile and food and drink industries), rising wages accompanying the labor productivity gains in industry, as well as access to cheap fertilizers, energy, farm machinery, and the abundance of land, one would expect the American agricultural sector to develop in line with the industrial sector. As noted by Habakkuk, "scarcity of labor ensured that, within the limits set by geology and climate, American agriculture developed along land-intensive, labor saving lines, that is, assumed high labor-productivity forms."[19] Studies of the American and British mining sectors also appear to suggest a greater US lead in productivity terms than suggested by Broadberry and Irwin. American miners were keen to take full advantage of the major improvements in labor-saving technologies – such as mechanized coal-cutting and electric lighting – whereas the British mine-owners generally displayed a conservative attitude toward these innovations.[20] Unfavorable geological conditions and a dwindling supply of natural resources in the UK explain this reflechesitant attitude and point at a much greater productivity potential in the US.[21]

In this chapter I revisit the Anglo-American benchmark around the year 1910. Similar to Broadberry and Irwin I opt for the industry-of-origin approach, as I agree with these authors that it is doubtful whether direct estimates of relative income and productivity between the US and UK should be based solely on expenditure benchmarks. The expenditure approach, as implemented by Ward and Devereux, establishes a direct link between comparative income levels and consumption possibilities, making those estimates particularly well suited for international comparisons of income and living standards. However, for the international comparisons of productivity and economic performance in general, a direct comparison of output at the industry level is preferable.[22] Whereas expenditure PPPs are influenced by imports, trade margins and transport costs, industry-of-origin conversion factors are based on ex-factory prices, excluding these elements. Industry-of-origin PPPs thus produce a more refined com-

18. A. Field, "Technological Change and US Productivity Growth in the Interwar Years," *Journal of Economic History* 66, no. 1 (2006): 203–236; also see chapter 3.

19. J. Habakkuk, *American and British Technology in the Nineteenth Century. The Search for Labour-saving Inventions* (Cambridge: Cambridge University Press, 1962), 34–7.

20. A. Taylor, "Labour Productivity and Technological Innovation in the British Coal Industry, 1850–1914," *Economic History Review* 14 (1961): 59; R. Walters, "Labour Productivity in South Wales Steam-coal Industry, 1870–1914," *Economic History Review* 28 (1975): 296.

21. D. McCloskey, "International Differences in Productivity? Coal and Steel in America and Britain Before World War I," chap. 11 in *Essays on a Mature Economy*, ed. D. McCloskey (Princeton: Princeton University Press, 1971), 293.

22. Ark, *International Comparisons of Output and Productivity*.

parison of labor productivity levels. More importantly, however, the expenditure approach does not allow for a breakdown of labor productivity at a sectoral level. The industry-of-origin approach provides a more in-depth view of the sources of growth and the effects of structural change. As I will illustrate in this chapter, these relative sectoral productivity differences and structural effects are key to understanding the Anglo-American comparative economic performance in the late nineteenth and early twentieth century. I focus my efforts on agricultural, mining and manufacturing, the sectors in which the US had the greatest productivity potential, but provide a comparative productivity for the total economy as well.

I find that, on the eve of the First World War, the gap between the US and the UK was larger than suggested by most previous studies in terms of relative income per head of the population. Compositional effects in general and a high level of productivity in American agriculture and mining in particular are instrumental in explaining these revised income per capita estimates. The UK appears to have ceded productivity leadership earlier than conventional estimates have shown. I date the US take-over around the 1880s and not post-1900, as suggested by Broadberry and Maddison.[23]

Section 2.2 provides an extensive discussion of the methods behind the benchmark comparison and presents an overview of the data sources used. My main results, the sectoral purchasing power parities and productivity levels, are presented in sections 2.3 and 2.4. I will discuss the implications for both the total-economy estimates as well as the time-series projections in section 2.5. In the last section I conclude.

2.2 Methodology and data

For the construction of my early twentieth century benchmark I opt for the industry-of-origin approach. My choice of industry-of-origin methodology does differ from the method applied by Broadberry and Irwin, however. The latter establish their sectoral productivity measures on the basis of a comparison of physical quantities of output, relying on a methodology first proposed in 1948 by Rostas.[24] The benefit of the quantity approach is that it is generally less demanding in terms of data requirements, which has made it the method of choice for direct benchmarks for the period prior to the Second World War. Data availability for the post-war period has allowed a more sophisticated methodology though, based on the calculation of real value added at the industry level using relative producer prices. Instead of a direct comparison of physical

23. Maddison, *Monitoring the World Economy*; Maddison, *The World Economy*; Broadberry, “Relative Per Capita Income Levels”;Broadberry and Irwin, “Labor Productivity in the United States and the United Kingdom.”

24. L. Rostas, *Comparative Productivity in British and American Industry* (Cambridge: Cambridge University Press, 1948).

quantities, this method measures the value of gross and net output by industry (in national currency) which is then translated into a common currency with a sector-specific purchasing power parity (PPP). This procedure was first applied by Paige and Bombach in an Anglo-American comparison for 1950.[25] The methodology behind these industry-of-origin benchmarks was subsequently further refined and used in a host of international benchmark comparisons for the post-war period; most notably the International Comparison of Output and Productivity (ICOP) project by Maddison and van Ark.[26] Recently however, the extended ICOP methodology has also been applied to international comparisons for the period preceding the Second World War.[27] These historical industry-of-origin studies not only prove that it is feasible to apply modern techniques for earlier periods, but they also stress the advantages of these methods over the earlier quantity based benchmark comparisons.

Although the basic concepts behind the available industry-of-origin benchmark techniques are similar, there are some marked differences between the ICOP and the earlier quantity approach. In this section I will only discuss the basic methodology behind the ICOP approach, but appendix 2.A provides an in-depth discussion of the methodological differences between both approaches. Here, I show that the quantity approach can be easily rewritten to approximate a basic version of the ICOP approach. I will also show, however, that in practice the outcomes of these methods can deviate substantially. Particularly the necessity, within the quantity approach, to assign labor to individual commodities instead of industries limits this method's ability to estimate productivity for industries producing a wide array of heterogeneous products. In addition, as I will illustrate below, the ICOP framework allows for differences in the relative prices of both outputs and inputs and takes differences between countries in their share of intermediate inputs in the value of gross output into account. I demonstrate the basic ICOP methodology on the basis of a simple single industry, two country, k product framework.

The ICOP approach

In the ICOP approach, the first step in the calculation of comparative labor productivity is the matching of products into unit values (p). The unit value, p_{ij}, which represents the local average price of commodity i in country j, can be obtained by dividing

25. D. Paige and G. Bombach, *A Comparison of National Output and Productivity of the United Kingdom and the United States* (Paris: Organisation for European Economic Co-operation, 1959).

26. A. Maddison and B. van Ark, "Comparison of Real Output in Manufacturing," *Policy, Planning and Research Working Papers* 5 (1988): 1–33; Ark, *International Comparisons of Output and Productivity*.

27. R. Fremdling, H. de Jong, and M. Timmer, "British and German Manufacturing Productivity Compared: A New Benchmark for 1935/36 Based on Double Deflated Value Added," *Journal of Economic History* 67 (2007): 350–378; J. Dormois, "Episodes in Catching-Up: Anglo-French Industrial Productivity Differentials in 1930," *European Review of Economic History* 8 (2004): 337–373; also see chapter 3.

the output value (v_{ij}) by the respective quantity (q_{ij}) for this product; as shown in equation (2.1) below. In a bilateral comparison, broadly defined products with similar characteristics are matched – e.g. iron ore, refined sugar, cement or bicycles – and the ratio of the unit values in both countries is taken; see equation (2.2).[28] These unit value ratios (uvr) thus reflect the product specific relative prices expressed in terms of country n's currency per unit of the base country o's currency.

$$p_{ij} = \frac{v_{ij}}{q_{ij}} \tag{2.1}$$

$$uvr_{io} = \frac{p_{in}}{p_{io}} \tag{2.2}$$

The $uvrs$ can then be aggregated to the industry level. For an industry which holds k matched products, the respective $uvrs$ are weighted according to their share in total matched output ($v_i / \sum v_i$). The resulting aggregated output $uvrs$ are generally referred to as purchasing power parities (PPP). In a bilateral comparisons the weights of either the base country (o) or the numerator country (n) can be used, which provide a Laspeyres and a Paasche type PPP respectively.[29] The Laspeyres gross output purchasing power parity, L^{go}, is then given by

$$L^{go} = \frac{\sum v_{io} \cdot \frac{p_{in}}{p_{io}}}{\sum v_{io}} = \frac{\sum v_{io} \cdot uvr_{io}}{\sum v_{io}} \tag{2.3}$$

whereas the Paasche gross output purchasing power parity, P^{go}, is given by

$$P^{go} = \frac{\sum v_{in}}{\sum v_{in} \cdot \frac{p_{io}}{p_{in}}} = \frac{\sum v_{in}}{\sum v_{in} / uvr_{io}} \tag{2.4}$$

Throughout this paper, I will use the geometric mean of the Laspeyres and Paasche price indices, the Fisher price index, as the currency conversion factor for my productivity comparisons; see equation (2.5). The Fisher PPPs, as well as the Paasche and Laspeyres PPPs, are still expressed in terms of country n's currency per unit of the

28. A complete list of the unit value ratios, on which the industry-specific PPPs presented in this chapter are based, is provided in appendix 2.B.

29. Fremdling, Jong, and Timmer, "British and German Manufacturing Productivity Compared," 14; Note that as v is equal to $p \cdot q$, the Laspeyres gross output PPP L^{go} can also be expressed as $\frac{\sum p_n \cdot q_o}{\sum p_o \cdot q_o}$, while the Paasche gross output PPP, P^{go}, is identical to $\frac{\sum p_n \cdot q_n}{\sum p_o \cdot q_n}$.

base country *o*'s currency, in line with the *uvrs* on which they are based.

$$F^{go} = \sqrt{L^{go} \cdot P^{go}} \tag{2.5}$$

As illustrated by Paige and Bombach, suitable conversion factors can be obtained from output price data alone (single deflation) or from price data for both outputs as well as intermediate inputs (double deflation).[30] Double deflation is generally considered to be the preferred approach for sector comparisons of output and productivity. A number of recent studies have shown that the adjustment for differences in the prices of intermediate inputs is particularly important for benchmark studies for the early twentieth century.[31]

Unfortunately, direct quantity and price information for inputs is not widely available in the early twentieth century British production statistics. For the construction of the intermediate input PPPs, I thus relied on implicit input-output relations instead. By definition inputs for one industry are made up of the output of other sectors and industries. The input PPP for an industry can thus be derived as a weighted set of output PPPs from the industries furnishing its inputs. For example, around 1900 the British food and drink industry obtained well over 60 percent of its inputs from the agricultural sector, while most of the remaining inputs originated from within the food and drink industry itself.[32] A weighted average of the output PPPs for the food and drink industry and the agricultural sector will thus provide a good proxy of the intermediate input PPP for the food and drink industry.

I relied on the Anglo-American Laspeyres and Paasche output PPPs, previously introduced, as the basis for my intermediate input PPPs. These were subsequently weighted on the basis of information on the flow of goods between sectors and industries from input-output tables. Note that this procedure does not take differences in the cost of transport or trade margins into account, which I implicitly assume to be similar for both countries (relative to total costs). Even if the trade and transport margins for both countries differ, however, the differences in these costs are unlikely to be so large as to have a substantial effect on the resulting input PPPs.

The equation for the derivation of the PPPs for intermediate inputs is similar to the calculation of the output PPPs in equations (2.3)-(2.5). The Laspeyres input PPP is

30. Paige and Bombach, *A Comparison of National Output and Productivity*, 82.

31. See chapter 3 and Fremdling, Jong, and Timmer, "British and German Manufacturing Productivity Compared."

32. In practice, a substantial proportion of the inputs consumed by an industry will originate from within this industry itself. This reflects the production of semi-manufactured, or partly finished goods, by separate establishments within an industry (e.g. flour mills) and the use of these intermediate products by establishments still part of this industry, but further down the production chain (e.g. bakeries).

given by

$$L^{ii} = \frac{\sum w_{io} \cdot L_i^{go}}{\sum w_{io}} \tag{2.6}$$

and the Paasche input PPP by

$$P^{ii} = \frac{\sum w_{in}}{\sum w_{in} / P_i^{go}} \tag{2.7}$$

where $w_i / \sum w_i$ represents the share of intermediate inputs supplied by industry i in the total of inputs consumed by the industry for which the PPP is calculated.

The output and input PPPs in turn allow me to calculate the double deflated value added PPPs. go_j and ii_j denote respectively the value of gross output and intermediate input for a single industry in country j, at national prices. The Laspeyres value added PPP, L^{va}, is given by

$$L^{va} = \frac{go_o \cdot L^{go} - ii_o \cdot L^{ii}}{go_o - ii_o} \tag{2.8}$$

while the Paasche value added PPP is given by

$$P^{va} = \frac{go_n - ii_n}{go_n / P^{go} - ii_n / P^{ii}} \tag{2.9}$$

Again, the Fisher value added PPP is derived as the geometric mean of the Laspeyres and Paasche price indices

$$F^{va} = \sqrt{L^{va} \cdot P^{va}} \tag{2.10}$$

The double deflated value added PPPs can in turn be used to convert either countries' output per unit of labor to the other countries' currency; see equation (2.12). Throughout this chapter I use value added (va) as the measure of output, as in (2.11). LP_o thus measures the industry-specific level of PPP-adjusted value added per worker in country n relative to the value added per worker in the base country o.

$$lp_j = \frac{va_j}{emp_j} \tag{2.11}$$

$$LP_o = \frac{lp_n / F^{va}}{lp_o} \tag{2.12}$$

Sources

The gross output PPPs presented in the next section are based on the official agricultural, mining and manufacturing production censuses of the United Kingdom and the United States. These surveys contain detailed information on quantities and values of produced items as well as average prices, enabling me to construct currency conversion factors bottom-up. For the US I based my PPPs on the agricultural, mining and manufacturing reports of the *Thirteenth Census of the United States*, all taken in the year 1909, as well as the *Mineral Resources of the Unites States* published as part of the United States Geological Survey for the year 1910.[33] For the UK I relied primarily on the *First Census of Production* of 1907 and the 1908 *Agricultural Output of Great Britain*.[34] Supplementary information for UK agriculture came from the *Agricultural Statistics*, while Fabricant provided additional information for a number of American manufacturing industries.[35]

Data on gross output, intermediate input, value added and employment was taken from a variety of sources. For the US, I primarily relied on output data for the year 1909 from the Historical Statistics, supplemented with data by King, Fabricant and the 1909 censuses of mining and manufacturing.[36] 1909 employment data was taken from Kendrick for all sectors except agriculture, which is based on figures by Lebergott.[37] Total gross domestic product is also based on Kendrick.[38] For the UK, 1907 gross domestic product, value added and employment are all based on figures by Feinstein, which is supplemented by data on the use of intermediate inputs from the

33. United States Department of Commerce: Bureau of the Census, "Agriculture," in *Thirteenth Census of the United States Taken in the Year 1910*, vol. V (Washington D.C.: United States Government Printing Office, 1913); United States Department of Commerce: Bureau of the Census, "Manufactures," in *Thirteenth Census of the United States*, vol. VIII; United States Department of Commerce: Bureau of the Census, "Mines and Quarries," in *Thirteenth Census of the United States*, vol. XI; United States Department of the Interior, *United States Geological Survey: Mineral Resources of the United States 1910* (Washington D.C.: United States Government Printing Office, 1911).

34. Board of Trade, *Final Report on the First Census of Production of the United Kingdom (1907)* (London: H.M. Stationery Office, 1912); Board of Agriculture and Fisheries, *The Agricultural Output of Great Britain (1908)* (London: H.M. Stationery Office, 1912).

35. Board of Agriculture and Fisheries, *Agricultural Statistics (1910)* (London: H.M. Stationery Office, 1911); S. Fabricant, *The Output of Manufacturing Industries, 1899–1937* (New York: National Bureau Economic Analysis, 1940).

36. S. Carter et al., eds., *Historical Statistics of the United States: Millennial Edition* (Cambridge: Cambridge University Press, 2006); W. King, *The National Income and Its Purchasing Power* (New York: National Bureau Economic Analysis, 1930); Fabricant, *The Output of Manufacturing Industries*; United States Department of Commerce: Bureau of the Census, "Manufactures"; United States Department of Commerce: Bureau of the Census, "Mines and Quarries."

37. Kendrick, *Productivity trends in the United States*, 308; S. Lebergott, *Manpower in Economic Growth: The American Record Since 1800* (New York: McGraw-Hill, 1964), 118.

38. Kendrick, *Productivity trends in the United States*, 296–7.

production censuses.[39] Population data for both countries was taken from Maddison's Historical Statistics.[40]

For the construction of the intermediate input PPPs, I relied on the 1899 American input-output table by Whitney and the input-output table for Edwardian Britain by Thomas.[41] I adjusted the row and column totals for both the US and UK input-output tables to match the level of gross output and intermediate input for the years 1909 and 1907 respectively. The totals for output and input were then translated to the cells of the matrix to create a fit as close as possible to the original input-output table.

The choice of benchmark years was at least partly determined by the availability of the production censuses listed above. For this benchmark comparison I took care to select two stable years on the eve of the First World War. Whenever possible I selected data from 1907 for the UK and 1909 for the US respectively. Table 2.2 shows that the unemployment rate at that point in time was relatively low or stable and that the actual per capita income level for the census years chosen was close to those of 1910. I see this as an essential requirement as I strive to determine the level of *potential* productivity differentials between the countries under comparison. I thus aim to exclude the effects of business cycles and capacity under-utilization as much as possible, which, I am convinced, is the case for the selected census years.[42]

2.3 Purchasing power parities

Table 2.3 presents my gross output PPP estimates at the sectoral level. These relative prices were constructed on the basis of 149 ex-factory and ex-farm unit value ratios for both intermediate and final goods. The sample of products in this study ranges from wheat to pigs meat for the agricultural sector, iron ore to petroleum in mining and jute yarn to sulfuric acid in manufacturing; a complete list is presented in appendix 2.B.

The number of matches for each sector and the value of these matched products in sectoral gross output (the coverage ratio) are shown in the first three columns of table 2.3. In agriculture and mining I was able to cover nearly 90 percent of total gross output in the UK and approximately 70 percent in the US. The coverage ratio for the man-

39. C. Feinstein, *National Income, Expenditure and Output of the United Kingdom, 1855–1965* (Cambridge: Cambridge University Press, 1972), 208; C. Feinstein, *Statistical Tables of National Income, Expenditure and Output of the UK, 1855–1965* (Cambridge: Cambridge University Press, 1976), T10, T125–6, T131; Board of Agriculture and Fisheries, *The Agricultural Output of Great Britain*; Board of Trade, *Final Report on the First Census of Production of the UK*.

40. A. Maddison, "Historical Statistics of the World Economy, 1–2008 AD," Groningen Growth & Development Centre, 2008.

41. W Whitney, *The Structure of the American Economy in the Late Nineteenth Century* (Cambridge: Harvard University Dissertation, 1968); M. Thomas, *An Input-Output Approach to the British Economy, 1890–1914* (Oxford: Nuffield College Dissertation, 1984), 152.

42. See chapter 3 for an elaborate discussion of the business cycle and capacity utilization effects and a sensitivity analysis for the interwar period.

Table 2.2: GDP per capita and unemployment, US and UK (1905–1913)

variables	*1905*	*1906*	*1907*	*1908*	*1909*	*1910*	*1911*	*1912*	*1913*
US GDPpc (1913=100)	75	84	85	79	88	89	92	96	100
UK GDPpc (1913=100)	87	89	91	87	89	92	95	96	100
US unemployment (%)	3.9	2.5	3.1	7.5	5.6	5.9	7.0	5.9	5.7
UK unemployment (%)	7.4	6.0	5.5	8.7	9.1	6.6	5.2	4.8	4.1

Source: US and UK Gross Domestic Product per capita, see A. Maddison, "Historical Statistics of the World Economy, 1–2008 AD," Groningen Growth & Development Centre, 2008, accessed on 11 March 2011; US unemployment, see D. Weir, "A Century of U.S. Unemployment, 1890–1990," *Research in Economic History* 14 (1992): 341–3; UK unemployment, see G. Boyer and T. Hatton, "New Estimates of British Unemployment, 1870–1913," *Journal of Economic History* 62 (2002): 662.

ufacturing sector was substantially lower, however, which is explained by the greater heterogeneity of products in this sector, as well as the unique national character and qualitative differences of some of the commodities produced. Nonetheless, I was able to cover well over 30 percent of the American and 40 percent of British manufacturing output. This is comparable to coverage ratios found in previous prewar productivity studies.[43]

Table 2.3 demonstrates that substantial relative price differences existed between the three main sectors at this time. The last column of this table compares the Fisher output PPPs to the 1909 US/UK exchange rate.[44] From this column we can see that the American mining products, which primarily consisted of coal, iron ore and petroleum, were relatively inexpensive as compared to the UK. In addition, American agricultural products were also relatively cheap, especially when compared to the price level of manufactured goods. Note that these large cross-industry variations in the output PPPs confirms that a uniform currency converter, such as the official exchange rate, will not generate accurate productivity comparisons at the sectoral level, since it rules out the possibility of inter-industry price differences.[45]

For this bilateral comparison, the weights of either the base country (UK) or the numerator country (US) can be used, which provide a Laspeyres- and a Paasche-type PPP respectively. The gap between both these indices can be interpreted as a measure

43. R. Fremdling, H. de Jong, and M. Timmer, "Censuses Compared: A New Benchmark for British and German Manufacturing 1935/1936," *Groningen Growth and Development Centre Memorandum* 90 (2007): 16; H. de Jong and P. Woltjer, "A Comparison of Real Output and Productivity for British and American Manufacturing in 1935," *Groningen Growth and Development Centre Memorandum* 108 (2009): 1–34.

44. Source for exchange rate: I. Svennilson, *Growth and Stagnation in the European Economy* (Geneva: United Nations, 1954), 318–9.

45. Paige and Bombach, *A Comparison of National Output and Productivity*.

Table 2.3: Gross output PPPs, US and UK (1909/07)

		coverage (%)		*gross output PPP ($/£)*			
branch/sector	*matches*	*US*	*UK*	*Las-peyres*	*Paasche*	*Fisher*	*rel. exch.*[a]
Agriculture	29	69	88	4.4	4.2	4.3	0.88
Mining	9	71	93	3.0	3.1	3.0	0.63
Manufacturing	111	33	46	5.5	4.6	5.1	1.04
Food, drink and tobacco	20	40	37	5.4	5.1	5.2	1.07
Textile and apparel	20	40	59	5.7	5.5	5.6	1.15
Lumber and wood products	3	7	1	4.0	3.9	3.9	0.81
Paper and printing	6	17	22	5.1	4.6	4.8	0.99
Chemicals and rubber	20	30	44	5.3	5.0	5.2	1.06
Petroleum and coal products	3	28	98	4.3	3.2	3.7	0.76
Leather and leather products	4	60	78	9.1	8.4	8.7	1.80
Stone, clay, and glass products	2	30	35	5.3	5.1	5.2	1.06
Metal industries	25	39	66	4.9	4.3	4.6	0.95
Machinery and transport eq.	5	20	19	4.8	4.0	4.4	0.90
Instruments and miscellaneous	3	9	4	8.2	7.4	7.8	1.60

[a] Fisher gross output PPP relative to exchange rate (4.87). Source for exchange rate, see I. Svennilson, *Growth and Stagnation in the European Economy* (Geneva: United Nations, 1954), 318–9.

Source: see text.

of the structural output diversity of both countries.[46] Only for the manufacturing sector do my estimates show a notable bias as the result of such structural differences (see table 2.3). The relatively low PPPs in mining and agricultural therefore do not appear to be the result of product specialization, but reflect the consistently lower American relative prices for the majority of sampled products in these sectors. Nonetheless, to overcome the potential structural bias, I rely on the geometric average of the Laspeyres and Paasche indices, the Fisher index, as the currency conversion factor for my productivity comparisons. As noted in section 2.2, this is considered common practice in this type of research.[47]

A further decomposition of the manufacturing sector offers additional insights into the price structure of these two economies. Table 2.3 reveals that the relative price differences across the manufacturing industries were quite substantial. These price differences testify to a specific pattern of industrial specialization, as already hinted at above by the substantial Paasche-Laspeyres spread for manufacturing as a whole. Whereas the textiles industries engaged the greatest share of British workers, American manufacturing was more geared toward the production of heavy and durable goods (metals, machinery, etc.). This is reflected in the relative price structure between the two countries as well. The PPP for the textile, apparel and leather industries rise above the manufacturing average, while the gross output PPP for metals and particularly the machinery and transportation equipment industries are below-average. Even within these branches considerable structural differences existed, again illustrated by the gap between the respective Paasche and Laspeyres PPPs. In the transportation equipment industries for instance, British producers were engaged primarily in the production of ships while the US transportation sector had already shifted its focus toward the production of automobiles.

Double deflation

The substantial differences in the gross output PPPs between the major sectors, observed in table 2.3, hint at a potential gap between relative output and input prices. Particularly the intermediate input PPPs for manufacturing industries that are dependent on inputs from the agriculture or mining sectors (e.g. food and metal products) are likely to deviate substantially from the single deflated gross output PPPs. As noted by Fremdling et al., "when relative prices of output and input differ across countries, single deflated productivity measures might be misleading." They demonstrate that

46. Generally, using a single countries' production shares as weights in the comparison will introduce a bias in the PPP as the products which constitute a large share of the total production are those for which the country sustains a comparative advantage and for which her prices will thus, by and large, be relatively low.

47. Ark, *International Comparisons of Output and Productivity*.

"single deflated measures can diverge substantially from double deflated measures when there are major differences in the technical input-output coefficients of an industry between two countries. This might be due to, for example, differences in production methods, the type of materials used, and the amount of imported material."[48]

Table 2.4 lists the intermediate input PPPs, in addition to the gross output PPPs discussed above. As illustrated in section 2.2, the intermediate input PPPs are based on *uvrs* of intermediate products weighted by data on the flow of these goods from input-output tables.[49] The intermediate input PPPs show a large cross-industry variation, although not as large as those observed for the gross output PPPs. The input PPPs for agriculture and particularly mining are below average, whereas the industries that rely on (semi-)manufactured goods – apparel and machinery, for instance – exhibit above-average PPPs.

On the basis of these gross output and intermediate input PPPs, I can now calculate the double deflated value added PPPs; see equations (2.8)-(2.10). The results for these value added PPPs are also shown in table 2.4. Given the similarity between input and output PPPs in the agriculture and mining sectors, combined with a relatively low share of intermediate inputs in gross output, the value added PPPs for these sectors stay close to the original single deflated output PPPs. For the manufacturing sector I do observe a notable gap between input and output PPPs, however. Table 2.4 shows that the relative US/UK price level for outputs was substantially higher than it was for inputs, which reflects the American access to cheap intermediate inputs flowing from the agricultural and mining sectors. These inputs represented a sizable portion of manufacturing gross output. For both countries, well over 50 percent of gross output consisted of intermediate inputs. Overall, the PPP for value added is raised by 13 percent (compared to the original manufacturing gross output PPP) to 5.74 \$/£, well above the official exchange rate, which stood at 4.87 \$/£ in 1909.[50]

2.4 Comparative labor productivity

What new light do these PPP estimates shed on the international labor-productivity comparison debate? Table 2.5 presents the comparative labor-productivity estimates with the UK as base-country. The first column of this table present the relative levels of gross output per worker, converted on the basis of the single deflated Fisher PPPs listed in table 2.4. The second column presents the comparative levels of real value

48. Fremdling, Jong, and Timmer, "Censuses Compared," 13.

49. For two manufacturing industries, leather and leather products and instruments and miscellaneous manufactures, information on the flow of inputs was missing, rendering the calculating of specific value added PPPs impossible.

50. Svennilson, *Growth and Stagnation in the European Economy*, 318–9.

Table 2.4: PPPs and intermediate input ratios, US and UK (1909/07)

	gross output PPP ($/£)			*int. input PPP ($/£)*			*value added PPP ($/£)*			*II/GO (%)*	
branch/sector	*Las-peyres*	*Paasche*	*Fisher*	*Las-peyres*	*Paasche*	*Fisher*	*Las-peyres*	*Paasche*	*Fisher*	*US*	*UK*
Agriculture	4.4	4.2	4.3	4.6	4.3	4.4	4.2	4.2	4.2	27	34
Mining	3.0	3.1	3.0	3.2	3.9	3.5	3.0	2.9	3.0	21	14
Manufacturing	5.5	4.6	5.1	5.1	4.4	4.7	6.4	5.1	5.7	59	67
Food, drink and tobacco	5.4	5.1	5.2	4.7	4.5	4.6	7.2	7.3	7.2	71	73
Textile and apparel	5.7	5.5	5.6	5.7	5.0	5.3	5.8	6.3	6.0	57	69
Lumber and wood products	4.0	3.9	3.9	4.4	4.0	4.2	3.5	3.8	3.6	46	56
Paper and printing	5.1	4.6	4.8	5.0	4.5	4.8	5.1	4.6	4.9	38	45
Chemicals and rubber products	5.3	5.0	5.2	4.9	4.6	4.7	6.4	5.8	6.1	61	71
Petroleum and coal products	4.3	3.2	3.7	3.0	3.4	3.2	7.3	2.7	4.4	78	71
Leather and leather products	9.1	8.4	8.7							67	70
Stone, clay, and glass products	5.3	5.1	5.2	3.5	3.9	3.7	6.4	6.0	6.2	35	39
Metal industries	4.9	4.3	4.6	4.6	4.0	4.3	6.0	5.2	5.6	67	76
Machinery and transport eq.	4.8	4.0	4.4	4.9	4.1	4.5	4.7	3.9	4.3	46	53
Instruments and miscellaneous	8.2	7.4	7.8							46	52

Source: see text.

Table 2.5: Comparative labor productivity, US and UK (1909/07)

	comparative labor productivity (UK=100)		
branch/sector	*single deflated gross output*[a]	*double deflated value added*[a]	*Broadberry & Irwin*[b]
Agriculture	159	181	109
Mining	278	263	161
Manufacturing	198	214	209

[a] *Source:* see text.

[b] *Source:* S. Broadberry and D. Irwin, "Labor Productivity in the United States and the United Kingdom During the Nineteenth Century," *Explorations in Economic History* 43 (2006): 261; S. Broadberry, "Forging Ahead, Falling Behind and Cathing-Up: A Sectoral Analysis of Anglo-American Productivity Differences, 1870-1990," *Research in Economic History* 17 (1997): 26–30; S. Broadberry, "Comparative Productivity in British and American Manufacturing During the Nineteenth Century," *Explorations in Economic History* 31 (1994): 524.

added per worker, converted using the double deflated Fisher PPPs of table 2.4. The latter represents my preferred estimate of Anglo-American productivity around 1910. The last column lists the figures by Broadberry and Irwin, the original benchmark of US/UK productivity for the early twentieth century. Broadberry and Irwin estimate productivity on the basis of a direct comparison of physical quantities of output per worker which, as discussed in appendix 2.A, makes them conceptually comparable to the single deflated productivity estimates listed in the first column of table 2.5.

So far my findings are in line with a large body of literature discussing the comparative advantages of the American economy during the late nineteenth and early twentieth century. The double deflated productivity figures in table 2.5 confirm the existence of a large transatlantic productivity gap in manufacturing, a phenomenon which has been extensively documented.[51] I find that the US manufacturing productivity level was about 214 percent of the UK. My new estimates underline the US dominance in mining productivity as well, even though I do find a substantially greater Anglo-American productivity gap for this sector than originally reported by Broadberry and Irwin. Contrary to the consensus view, however, the present study also highlights the comparatively strong performance of the American agricultural sector. Below I will show that these upward revisions of sectoral productivity levels, particularly those for agriculture, raise the benchmark estimate of American total-economy productivity

51. See for instance: Rostas, *Comparative Productivity in British and American Industry*; Broadberry, *The Productivity Race*; Field, "The Most Technologically Progressive Decade of the Century"; R. Gordon, "Two Centuries of Economic Growth: Europe Chasing the American Frontier," *Centre for Economic Policy Research Discussion Paper* 4415 (2004): 1–48.

relative to the UK. This brings my aggregate estimates much closer to the GDP per worker and GDP per capita figures reported by Ward and Devereux and directly challenge the conclusions made by Broadberry and Irwin. Prior to discussing the results at the total-economy level, I will first discuss the origin and rational behind the revisions for each of the major sectors individually.

Agriculture

The main source for the discrepancy in the agricultural labor productivity estimates is not the method of productivity comparison – as Broadberry and Irwin also applied the ICOP approach here – but is the underlying figure of US value added per worker for this sector. Table 2.6 provides an overview of the sources and figures behind both Anglo-American comparisons of agricultural productivity. In an earlier study, on which Broadberry and Irwin base their estimate, Broadberry lists a US net output per employee value of 347$.[52] I base my considerably higher estimate of 488$ per worker on the value added figures listed in the Historical Statistics and the agricultural employment reported by Lebergott.[53] Although the estimation of employment and particularly value added in agriculture is considerably more difficult than it is for other sectors, none of the primary sources point in the direction of a figure as low as suggested by Broadberry.[54]

Although Broadberry does not list the value added and employment figures underlying his labor productivity figures in US agriculture directly, they can be implicitly derived on the basis of the sectoral employment shares listed in his paper.[55] Table 2.6 shows that this employment figure broadly matches the estimate by Lebergott, on which I rely.[56] Total value added in the agricultural sector, derived from the productivity figure listed by Broadberry and the implicit employment estimate, lies considerably

52. Broadberry, "Forging Ahead, Falling Behind and Cathing-Up," 27.
53. Carter et al., *Historical Statistics of the United States*, 4:193; Lebergott, *Manpower in Economic Growth*, 510.
54. Cited estimates of US value added per worker in 1910 range from 426$ to 575$. For alternative sources on employment see: Kendrick, *Productivity trends in the United States*, 308; Carter et al., *Historical Statistics of the United States*, 4:77; United States Department of Commerce: Bureau of the Census, "Population," in *Thirteenth Census of the United States*, IV:40; United States Department of Commerce: Bureau of Foreign and Domestic Commerce, *Statistical Abstract of the United States (1913)*, 36 (Washington D.C.: United States Government Printing Office, 1914), 229; United States Department of Commerce: Bureau of the Census, "Population: Comparative Occupation Statistics for the United States, 1870 to 1940," in *Sixteenth Decennial Census of the United States* (Washington D.C.: United States Government Printing Office, 1942), 104. For alternative sources on agricultural output see: United States Department of Agriculture, "Value Added to the U.S. Economy by the Agricultural Sector Via the Production of Goods and Services, 1910–1919," 2011, accessed on 1 November 2011; United States Department of Commerce: Bureau of the Census, "Agriculture," 474, 494, 505, 517, 519, 532.
55. Broadberry, "Comparative Productivity in British and American Manufacturing," 524; Broadberry and Irwin, "Labor Productivity in the United States and the United Kingdom," 261.
56. Lebergott, *Manpower in Economic Growth*, 510.

Table 2.6: Value added, employment and PPPs in agriculture, US and UK (1909/07)

	United States (1909)			*United Kingdom (1907)*				*comp.*
	value added ($ mln.)	*employ-ment (th.)*	*labor prod. ($ th.)*	*value added (£ mln.)*	*employ-ment (th.)*	*labor prod. (£ th.)*	*PPP ($/£)*	*labor prod. (UK=100)*
This study[a]	5,780	11,838	488	143	2,234	64	4.20	181
Broadberry & Irwin[b]	*3,875*	*11,167*	347	[...]	[...]	78	4.12	109

[a] *Source:* US value added: S. Carter et al., eds., *Historical Statistics of the United States: Millennial Edition* (Cambridge: Cambridge University Press, 2006), 4:193; US employment: S. Lebergott, *Manpower in Economic Growth: The American Record Since 1800* (New York: McGraw-Hill, 1964), 510; UK value added: C. Feinstein, *National Income, Expenditure and Output of the United Kingdom, 1855–1965* (Cambridge: Cambridge University Press, 1972), 208; C. Feinstein, *Statistical Tables of National Income, Expenditure and Output of the UK, 1855–1965* (Cambridge: Cambridge University Press, 1976), T10; UK employment: C. Feinstein, *Statistical Tables of National Income, Expenditure and Output of the UK, 1855–1965* (Cambridge: Cambridge University Press, 1976), T60, T131; PPP: double deflated value added Fisher PPP, table 2.4.

[b] *Source:* S. Broadberry and D. Irwin, "Labor Productivity in the United States and the United Kingdom During the Nineteenth Century," *Explorations in Economic History* 43 (2006): 261; S. Broadberry, "Comparative Productivity in British and American Manufacturing During the Nineteenth Century," *Explorations in Economic History* 31 (1994): 524; US employment (in italics) based on sectoral distribution of labor as listed in S. Broadberry and D. Irwin, "Labor Productivity in the United States and the United Kingdom During the Nineteenth Century," *Explorations in Economic History* 43 (2006): 262.

below my own measure, however. Broadberry's figure of approximately 3,875 million dollars does not appear to be supported by any of the primary sources available, which cite figures of total value added in agriculture ranging from 5,780 million to 6,077 million dollars.[57] Broadberry's underestimation of American agricultural output by over 30 percent accounts for a large share of the difference between his comparative productivity figure and those presented in the present study.

In addition, net output per worker in the British agricultural sector appears to be overstated by Broadberry; 78£ versus my estimate of 64£.[58] The higher estimate by Broadberry is the result of his choice to exclude the agricultural production in Ireland from his productivity estimate. This, however, is inconsistent with the definition used by Feinstein as well as the industrial benchmark.[59] I reincorporated Irish production and employment in the productivity figures and made a (minor) revision to the PPP – from 4.12 $/£ listed by Broadberry to 4.20 $/£.[60]

These adjustments to the productivity estimates listed above are not only in line with those suggested in a recent paper by Ward and Devereux, they also substantiate Habakkuk's claim of relatively high levels of productivity in American agriculture.[61] In his monograph, Habakkuk argues that during the nineteenth century "America[n] improvements in agriculture took the form primarily of increasing output per head and the increase initially was probably more rapid than in industry; in England on the other hand, agricultural improvement was devoted primarily to increasing yields per acre."[62] Reflecting his well-known thesis for industry, Habakkuk contends that the abundance of resources and scarcity of (skilled) labor in the US forced American farmers to pursue capital-intensive methods of production. Machinery and particularly land were substituted for labor, resulting in high levels of labor productivity. The importance of labor-saving innovations also features prominently in subsequent accounts of the American agricultural development, stressing the relative productivity of this sector in international perspective.[63] Furthermore, Olmstead and Rhode demonstrate the importance of biological innovations in the form of improved crops

57. Carter et al., *Historical Statistics of the United States*, 4:193; United States Department of Agriculture, "Value Added to the U.S. Economy by the Agricultural Sector," accessed on 1 November 2011; United States Department of Commerce: Bureau of the Census, "Agriculture," 474, 494, 505, 517, 519, 532.

58. Broadberry, "Forging Ahead, Falling Behind and Cathing-Up," 27; Feinstein, *National Income, Expenditure and Output of the United Kingdom*, 208; Feinstein, *Statistical Tables of National Income, Expenditure and Output of the UK*, T60, T131; Board of Agriculture and Fisheries, *The Agricultural Output of Great Britain*, 17, 26; Board of Trade, *Final Report on the First Census of Production of the UK*, 20.

59. Feinstein, *National Income, Expenditure and Output of the United Kingdom*.

60. Broadberry, "Forging Ahead, Falling Behind and Cathing-Up," 27.

61. M. Ward and J. Devereux, "Relative British and American Income Levels During the First Industrial Revolution," *Research in Economic History* 23 (2005): 267–8.

62. Habakkuk, *American and British Technology in the Nineteenth Century*, 11–4.

63. W. Hayami and V. Ruttan, *Agricultural Development: An International Perspective* (Baltimore: John Hopkins University Press, 1985).

and livestock.[64] These biological innovations allowed the farm frontier to be pushed to the drier and harsher West and North, continuously expanding the available land for cultivation. This depressed the price of farmland in relation to labor even further. These developments allowed American agriculture to become regionally specialized, reaping all the benefits of returns-to-scale and raising productivity levels in the process.

The developments in American agriculture should not be viewed in isolation. As noted in section 2.1, it appears highly unlikely that the American agricultural sector was left entirely unaffected by the rapid developments in industry during the late nineteenth and early twentieth century. Demand for agricultural goods increased dramatically, both from the domestic as well as the international market, while the wage-level continued to rise, reflecting the sizable labor productivity gains in industry. Had productivity levels in agriculture remained stagnant, it would have become even more difficult to attract labor from the industrial areas of the US. This in itself would have provided further incentive for farmers to economize on labor and adopt even more land-intensive forms of agriculture, raising labor productivity in the process. Over and above, American industry provided farmers with cheap fertilizers, energy and farm machinery which had the effect of raising the output per acre as well as allowing farmers to work greater stretches of land unaided.

In the UK land was scarce and there were few opportunities to expand the arable acreage. Consequently, British farmers primarily adopted land-saving, as opposed to labor-saving improvements and were mostly interested in raising the output per acre.[65] In an attempt to overcome this barrier, from the 1840s to the 1870s – the period known as 'high farming' – a considerable amount of new acreage was added, mostly through drainage.[66] Still, this investment came at considerable expense and the supplemental farmland, approximately 4.5 million acres, was not enough to overcome the constraints posed by land-scarcity on the growth prospects of British agriculture. Doubt could thus be cast on the appropriateness of the designation 'high farming', as it is not evident that the addition of arable acreage made strict economic sense.[67] From 1870 up to the First World War, other forms of land-saving technologies developed rapidly and began to spread across British agriculture; the primary applications were the use of chemical fertilizers and concentrated feeds.[68] When compared to other

64. A. Olmstead and P. Rhode, *Creating Abundance: Biological Innovation and American Agricultural Development* (New York: Cambridge University Press, 2008).
65. Habakkuk, *American and British Technology in the Nineteenth Century*, 101–2.
66. M. Turner, "Agriculture, 1860–1914," chap. 6 in Floud and Johnson, *The Cambridge Economic History of Modern Britain*, 2:139.
67. ibid., 139.
68. J. van Zanden, "The First Green Revolution: The Growth of Production and Productivity in European Agriculture, 1810–1914," *Economic History Review* 44 (1991): 231–2.

Western-European countries though, the average consumption of fertilizers in the UK was still relatively low, while the level of consumption of imported animal feeds stagnated after 1880.[69] In contrast to the US and parts of Europe, the improvements in labor-saving technology in late nineteenth and early twentieth century Britain were limited and the main agricultural activities remained largely dependent on draft animals and human labor.[70]

As noted by Turner, British agriculture appears to have been in more or less unremitting decline from 1860 down to the First World War.[71] The UK became more and more dependent on imports of agricultural goods to satisfy the needs of the ever-growing urban population. Initially this flow of imports was composed largely of cash crops, such as wheat from North America. The influx of cheap grains caused a sharp realignment of the agricultural sector from crop production toward a livestock economy.[72] In the 1860s and 1870s, Britain's isolated position and legislation still afforded the livestock producers some respite from foreign competition, and livestock's share in total agricultural output increased to well over 50 percent during the decades to follow. Yet, by the 1880s the free-trade policies and the development of chilled transportation opened the British meat market to foreign competition. Turner shows that, "the benefits of bulk carriage and the attendant economies of scale meant that even after incurring substantial freight charges many overseas suppliers from the 1880s could compete more successfully in home markets than home producers."[73]

The inability of British farmers to compete with foreign competitors and the substantial imports of American agricultural produce appear to support my finding of comparatively low levels of productivity in the British agricultural sector. This also aligns with Ó Gráda's estimates of TFP growth in the range of 0.4 percent per year between 1870 and 1910, which in comparison to the US and other European countries was fairly slow.[74] Whereas American agriculture took full advantage of the major improvements in labor-saving technologies prior to 1910, British improvements focused primarily on the saving of land. By and large British farmers had trouble adapting to the rapidly changing economic and social conditions.[75]

69. ibid., 232.
70. ibid., 234.
71. Turner, "Agriculture, 1860–1914," 133.
72. ibid., 144.
73. ibid., 134.
74. C. Ó Gráda, "British Agriculture, 1860–1914," chap. 6 in *The Economic History of Britain Since 1700*, 2nd ed., ed. R. Floud and D. McCloskey, vol. 2 (Cambridge: Cambridge University Press, 1994), 148–9; Zanden, "The First Green Revolution," 229.
75. ibid., 237–8.

Table 2.7: Value added and employment shares in mining, US and UK (%, 1909/07)

	United States (1909)[a]		*United Kingdom (1907)*[b]	
branch/sector	*value added*	*employment*	*value added*	*employment*
Coal	49.3	68.8	91.0	87.9
Iron ore	8.8	4.8	1.5	1.2
Other metals	19.4	10.7	1.1	1.9
Fuel oils	13.9	4.4	1.3	1.0
Miscellaneous	8.5	11.3	5.1	8.1
Total mining	100.0	100.0	100.0	100.0

[a] *Source:* United States Department of Commerce: Bureau of the Census, "Mines and Quarries," in *Thirteenth Census of the United States*, XI:24.
[b] *Source:* Board of Trade, *Final Report on the First Census of Production of the United Kingdom (1907)* (London: H.M. Stationery Office, 1912), 39.

Mining

The estimate of labor productivity for mining by Broadberry and Irwin again appears to understate the relative lead of the US in comparison to the UK. The double deflated figures of value added per worker, listed in table 2.5, appraise American mining at 263 percent of the UK level. Broadberry and Irwin cite an estimate of 161. The main source for the discrepancy between both benchmark estimates is the method of productivity comparison. Broadberry and Irwin rely on Rostas' original quantity approach and estimate comparative productivity in mining solely on the basis of the physical production of coal and iron ore. Even though coal and iron ore comprise the bulk of output and employment in this sector, as shown in table 2.7, by focusing solely on these two items Broadberry and Irwin ignore the contribution of other upcoming mining products, most notably gas and fuel oils (e.g. petroleum).[76]

The average value added per wage earner in these uncovered mining branches – at least for the American mining sector – was substantially greater than that observed in coal and iron ore mining. Table 2.7 shows that the nonferrous metal ores, fuel oils and miscellaneous mining branches covered approximately 26 percent of employment and 42 percent of value added in US mining, raising the average labor productivity by about 27 percent when I include these to the coal and iron ore sample. For the

76. Even though the share of oil and natural gas in the world's total energy consumption was still fairly low prior to the First World War (approximately 5.9 percent), their relative contribution to the total power supply increased rapidly in the decades to follow; by 1935 the share of these commodities in the world's power supply had risen to just over 20 percent. The American reliance on gas and oil was substantial greater than it was in the UK, however. According to the International Labour Office, in 1936 the American share of oil and gas in the total energy consumption was 37.4 percent, whereas the British share was only 8.7 percent. International Labour Office, *The World Coal-mining Industry*, vol. I (Geneva, 1938), 33–6.

UK, coal and iron ore already encompassed 89 percent of mining employment and about 93 percent of value added. Here, the addition of the other mining branches actually lowers the average value added per worker for the total British mining sector by 4 percent. The complete coverage of mining, which is made possible by the use of the ICOP methodology, thus raises the comparative productivity estimate by over 30 percent in favor of the US, accounting for a large part of the discrepancy between my new estimate and the original Broadberry and Irwin benchmark.

Apart from its limited coverage, the figure cited by Broadberry and Irwin also appears to understate productivity in coal mining directly. Given coal's large share in mining output, the estimate for this branch has serious implications for both Broadberry and Irwin's as well as my own estimation of overall mining productivity. Broadberry and Irwin's estimate is based on earlier work by Broadberry, who cites the total tonnage of coal extracted and the number of wage earners in American and British coal mining.[77] In his figures Broadberry erroneously includes the labor and output of the coke production at the American collieries. This lowers his estimate of output per worker for the US substantially. In an earlier study, McCloskey uses identical methods and sources to compare Anglo-American productivity in the coal mining branch, but he adjusts the output and employment figures to exclude the production of coke.[78] Table 2.8 lists both these estimates and the underlying country-specific output per worker figures, showing McCloskey's comparative US/UK productivity figure for coal mining to come out substantially higher at 188 compared to the Broadberry estimate of 163.[79]

On the basis of the same sources as McCloskey, but comparing the gross output value per wage earner instead, I arrive at an identical level of comparative productivity (see row 3 in table 2.8). For this estimate, I converted US gross output per wage earner to British Pounds Sterling on the basis of the ratio of the American and British unit values for all types of coal combined.[80] This is in line with the approach taken by Broadberry and McCloskey who also aggregated the total tonnage of coal excavated prior to comparing the quantity output per worker. The aggregation of the total tonnage and output value of coal implicitly ignores the variations in the quality and price

77. Broadberry, "Forging Ahead, Falling Behind and Cathing-Up," 27.

78. McCloskey, "International Differences in Productivity?," 291.

79. An international comparison of the coal-mining industry by the International Labour Office reports an even greater gap in productivity between the US and UK. Comparing the output of bituminous coal per man-shift in 1913 they observe an average production of 3,270 kg. per shift in the US and only 1,090 in Britain. Relative to other European countries, productivity in the UK was slightly above-average; productivity in the German Ruhr area was approximately 943 kg. per shift; for Belgium the ILO reports a figure of 528; 701 for France; 820 for the Netherlands; and 1,202 for the East Upper Silesia region in Poland. International Labour Office, *The World Coal-mining Industry*, 109.

80. The unit values and unit value ratios for coal are based on equations (2.1) and (2.2). The underlying quantity and value data and sources are given in table 2.9.

Table 2.8: Comparative labor productivity in coal mining, US and UK (1909/07)

	unit	output per worker US	output per worker UK	PPP ($/£)	comparative productivity (UK=100)
Quantity: Broadberry[a]	tons/worker	530	326		163
Quantity: McCloskey[b]	tons/worker	613	325		188
ICOP: *uvr* 'coal: total'[c]	*go*/worker	826	146	3.01	188
ICOP: Fisher PPP[d]	*go*/worker	826	146	2.78	203

[a] *Source:* Broadberry, "Forging Ahead, Falling Behind and Cathing-Up," 27.
[b] *Source:* McCloskey, "International Differences in Productivity?," 291.
[c] *Source:* Board of Trade, *Final Report on the First Census of Production of the UK*, 42, 44; United States Department of Commerce: Bureau of the Census, "Mines and Quarries," 186. The employment figures for the US were adjusted to exclude coke workers and take peak employment into account, while British employment was corrected for absenteeism and excludes iron miners working under the Coal Mines Regulation Act; see McCloskey, "International Differences in Productivity?," 291. The price deflator is based on the unit value ratio for all coal combined, see table 2.9.
[d] *Source:* see [c]. The price deflator is based on the Fisher PPP for coal, see table 2.9.

for the different types of coal, however. Table 2.9 illustrates that in both countries the price for anthracite coal was markedly higher than the price for bituminous coal, and that the share of the former in the output of the American coal mining branch was also substantially greater than the share of anthracite in British coal production. As an alternative measure, using equations (2.3)-(2.5), I estimated a new purchasing power parity for coal, taking both the price variations and the different value shares of anthracite and bituminous coal into account. This Fisher PPP was then used to re-estimate comparative productivity in table 2.8, resulting in a US/UK productivity level of 203.

The example of coal mining above highlights both the similarities between the quantity and the ICOP approach as well as the potential advantages of the latter. Based on the same sources, a direct comparison of the tonnage of coal per worker yields an identical productivity estimate as a comparison of the per worker value of coal production (based on the unadjusted average price of coal). The capacity of the ICOP approach to account for differences in prices between the various commodities produced within the same industry distinguishes it from the original quantity approach, however. Still, it should be noted that the quality adjustment illustrated above does not guarantee that the products being compared are fully equivalent between the two countries. The chemical composition of coal (e.g. carbon, moisture or volatile content) as well as the physical characteristics – which can differ markedly between geological

Table 2.9: Relative price of coal, US and UK (1909/07)

	United States (1909)[a]			*United Kingdom (1907)*[b]			
	quantity (ton, mln.)	*value ($, mln.)*	*unit value ($/ton)*	*quantity (ton, mln.)*	*value (£, mln.)*	*unit value (£/ton)*	*uvr ($/£)*
coal: anthracite	73.5	149.4	2.03	4.0	2.3	0.58	3.51
coal: bituminous	344.5	405.5	1.18	266.9	117.3	0.44	2.68
coal: total	418.0	554.9	1.33	270.8	119.6	0.44	**3.01**
	Laspeyres	*Paasche*	*Fisher*				
PPP	2.69	2.86	**2.78**				

[a] *Source:* United States Department of the Interior, *United States Geological Survey: Mineral Resources of the United States 1910* (Washington D.C.: United States Government Printing Office, 1911);
United States Department of Commerce: Bureau of Foreign and Domestic Commerce, *Statistical Abstract of the United States (1910)*, 33 (Washington D.C.: United States Government Printing Office, 1911), 202–4.

[b] *Source:* Board of Trade, *Final Report on the First Census of Production of the United Kingdom (1907)* (London: H.M. Stationery Office, 1912), 42.

regions – ultimately determine the suitability for specific consumption purposes.[81] In the early twentieth century, the world's coal markets recognized hundreds of individual classifications of coal, illustrating that the distinction between anthracite and bituminous coal is still fairly rough.[82] Nonetheless, the expanded sample of products discussed previously, as well as the reliance on value added and sectoral employment figures and the application of double deflation in the present study, yields a markedly higher and, in my opinion, more representative estimate for the comparative Anglo-American productivity in the mining sector as a whole.

The superior performance of the American mining sector can, in part, be explained by the sheer quantity and quality of natural resources in this country. For the coal-mining sector, McCloskey shows that the "American seams were generally thicker, closer to the surface, freer from faults, flatter and drier than British seams."[83] The favorable geological conditions allowed American miners to introduce new mechanized methods of production and work considerably more efficiently than their British counterparts. Taylor illustrates the British mine-owners conservative attitude toward the

81. The International Labour Office report on the world coal-mining industry provides an extensive description of the characteristics of different ranks and grades of coal and their consumption purposes, see International Labour Office, *The World Coal-mining Industry*, 17–24.

82. Neither the British nor the American census fully distinguish between bituminous, sub-bituminous and even lignite. See, United States Department of Commerce: Bureau of Foreign and Domestic Commerce, *Statistical Abstract of the United States (1910)*, 33 (Washington D.C.: United States Government Printing Office, 1911), 203; Board of Trade, *Final Report on the First Census of Production of the UK*, 42–3.

83. McCloskey, "International Differences in Productivity?," 293.

adoption of new innovations and technologies through, for instance, the late adoption of electricity as well as the hesitant introduction of the mechanized coal-cutter in the British mines.[84] "By 1913 almost nine times as much coal was being cut by machine in the United States as in Britain."[85] As was the case for agriculture, American miners took full advantage of the major improvements in labor-saving technologies during the late nineteenth and early twentieth century, whereas British improvements focused primarily on overcoming the diminishing returns to land as the coal and ore deposits were slowly being exhausted.[86] These developments drove a wedge between the labor productivity levels of both countries, resulting in a productivity ratio in the mining sector of 2.63 to 1 in favor of the US.

Manufacturing

As illustrated in table 2.5, the estimate of labor productivity in manufacturing by Broadberry and Irwin is actually very close to my own double deflated value added per worker figure for this sector. Broadberry and Irwin estimate a US/UK comparative productivity level of 209 versus my estimate of 214. Both these estimates confirm the existence of a large transatlantic productivity gap for manufacturing in the early twentieth century. Britain's falling behind during the nineteenth century and its inability to catch-up has been extensively documented and has traditionally been explained by differences in factor and resource endowments as well as demand patterns.[87] The abundance of land and natural resources in the US gave rise to more capital- and resource-intensive production, a process which was further facilitated by a relatively homogenous demand for goods.[88] In contrast, in Britain natural resources were scarce while skilled labor was in ample supply, providing an incentive to economize on fixed capital in the form of machinery.[89] The role played by resources in the Anglo-American manufacturing productivity gap is underscored by the relatively low input PPP for manufacturing, presented in table 2.4, which illustrates the American access to cheap intermediates flowing from the agricultural and mining sectors.

Table 2.10 shows that the new comparative labor productivity figures for the underlying industries deviate more substantially from the original estimates. Still, the overall picture sketched by Broadberry and Irwin remains intact. American producers ex-

84. Taylor, "Labour Productivity and Technological Innovation in the British Coal Industry," 59; see also, Walters, "Labour Productivity in South Wales Steam-coal Industry," 296.
85. Taylor, "Labour Productivity and Technological Innovation in the British Coal Industry," 58.
86. McCloskey, "International Differences in Productivity?," 289–90.
87. Habakkuk, *American and British Technology in the Nineteenth Century*; Broadberry, *The Productivity Race*; Field, "The Most Technologically Progressive Decade of the Century"; Gordon, "Two Centuries of Economic Growth."
88. Broadberry, "Technological Leadership and Productivity Leadership in Manufacturing," 291.
89. P. Temin, "Labour Scarcity in America," *Journal of Interdisciplinary History* Vol. 1 (1971): 162.

Table 2.10: Comparative labor productivity in manufacturing, US and UK (1909/07)

	comparative labor productivity (UK=100)		
industry/sector	*single deflated gross output*	*double deflated value added*	*Broadberry & Irwin*[a]
Food, drink and tobacco	200	155	146
Textile, apparel and leather	157	184	151
Chemicals, petroleum and rubber	169	176	143
Metal industries	203	224	288
Engineering and transport eq.	227	268	203
Miscellaneous	216	239	227
Manufacturing	198	214	209

[a] *Source:* S. Broadberry and D. Irwin, "Labor Productivity in the United States and the United Kingdom During the Nineteenth Century," *Explorations in Economic History* 43 (2006): 261; S. Broadberry, "Comparative Productivity in British and American Manufacturing During the Nineteenth Century," *Explorations in Economic History* 31 (1994): 524.

celled in the production of durable goods (e.g. metal, engineering and wood products), while the British manufactures were relatively productive in the non-durable industries (e.g. food, textile and chemicals). As noted by Broadberry, the industry-specific productivity results are also broadly in line with the figures on revealed comparative advantage in British and American manufacturing trade by Crafts and Thomas.[90]

A comparison of the real gross output and real value added figures in table 2.10 reveals that the application of the double deflation procedure can have a significant impact on the productivity estimates. As previously noted, the use of gross output in international benchmark comparisons introduces a potential bias as a result of differences in the share of inter-industry deliveries in the value of production. This is of importance particularly when the ratio of intermediate inputs to gross output varies between countries as well as industries. These variations can occur as a result of differences in production methods, the types of materials used, and the amount of imported materials, but can also be caused by differences in industry classifications between the countries under comparison.[91] In addition, as discussed in section 2.3, double deflation takes both relative prices of output and inputs into account. The difference between the use of value added instead of gross output for the productivity comparison is most evident for the engineering and transportation equipment sector. Here the rel-

90. Broadberry, "Technological Leadership and Productivity Leadership in Manufacturing," 523; N. Crafts and M. Thomas, "Comparative Advantage in UK Manufacturing Trade, 1910–1935," *Economic Journal* 96 (1986): 639.

91. Fremdling, Jong, and Timmer, "British and German Manufacturing Productivity Compared," 360.

ative input and output prices vary only marginally, but the share of input in gross output is relatively high in the UK (see table 2.4). Consequently, British gross output is inflated by the large share of intermediates used in the production process and will considerably overestimate the added value of British machine builders in comparison to their American counterparts. In contrast, the share of intermediate inputs in the food, drink and tobacco industry is roughly identical for the UK and the US (73 and 71 percent respectively), but the use of relatively cheap agricultural inputs in the US leads to a considerable upward adjustment of the value added PPP. Taking the relative prices for outputs as well as inputs into account thus results in a substantial downward adjustment of the comparative productivity figure for this industry.

In appendix 2.A, I demonstrate that the quantity approach – the method on which Broadberry and Irwin rely – is conceptually on the same footing as my measure of real gross output per worker. For the textile, apparel and leather as well as the engineering and transportation equipment industries, the gap between the new productivity figures and the original estimates by Broadberry and Irwin appear to be explained by the latter's implicit reliance on gross output instead of value added. The moderate upward revision for the productivity estimates in the chemical industries illustrates one of the drawbacks of the quantity approach. Because of the complex structure of the chemical industries and the heterogeneous nature of its products, it is simply not possible to aggregate the quantities produced to a single measure or to assign labor to the various products. The assignment of labor used to produce a single good, as discussed in appendix 2.A, is economically less sensible when the share of output for that good only comprises a small fraction of the total production value in that industry. As a result, the Broadberry and Irwin estimate for chemicals is primarily based on those chemical industries that produce a single or homogeneous set of products (e.g. seed crushing, coke, soap, fertilizers), disregarding the biggest industry in this sector: basic chemicals.

Hours of work

So far the productivity figures have been expressed solely in terms of output per worker. I implicitly assumed the average length of the working week as well as the number of vacation and holidays to be identical in both countries. This assumption is born out of necessity, unfortunately, as detailed figures on hours of work are generally unavailable for most sectors in the early twentieth century. For the manufacturing industries, however, statistics on the length of the working week are available. Table 2.11 provides an overview of the weekly and annual hours of work in both countries.

The UK figures in table 2.11 were taken from the *British Labour Statistics*, which

Table 2.11: Weekly and annual average hours worked in manufacturing, US and UK (1909/06)

	United States (1909)[a]		*United Kingdom (1906)*[b]	
branch/sector	*weekly hours*	*annual hours*	*weekly hours*	*annual hours*
Food, drink and tobacco	54.7	2,722	54.4	2,657
Textile, apparel and leather	54.2	2,697	53.9	2,631
Chemicals, petroleum and rubber	56.9	2,827	53.2	2,597
Metal industries	55.5	2,760	53.1	2,593
Engineering and transport eq.	54.2	2,692	53.2	2,596
Miscellaneous	54.3	2,699	53.6	2,617
Manufacturing	54.7	2,718	53.7	2,619

[a] *Source:* United States Department of Commerce: Bureau of the Census, "Manufactures," in *Thirteenth Census of the United States*, VIII:316–9; E. Jones, "New Estimates of Hours of Work per Week and Hourly Earnings, 1900–1957," *Review of Economics and Statistics* 45 (1963): 375; M. Huberman and C. Minns, "The Times They are not Changin': Days and Hours of Work in Old and New Worlds, 1870–2000," *Explorations in Economic History* 44 (2007): 546.

[b] *Source:* Great Britain Department of Employment and Productivity, *British Labour Statistics: Historical Abstract 1886–1968* (London: H.M. Stationery Office, 1971), 95; R. Matthews, C. Feinstein, and J. Odling-Smee, *British Economic Growth, 1856–1973* (Oxford: Clarendon Press, 1982), 566.

contains detailed statistics on the 1906 average hours of work per week for nearly all of the large industries within the British manufacturing sector.[92] The American industry-specific estimates were taken from the *Census of Manufactures* of 1909 and the work of Jones.[93] Data from Matthews, Feinstein and Odling-Smee on the number of vacations and holidays in Britain and Huberman and Minns for the US allowed me to estimate the annual totals for hours worked.[94] Overall, the length of the average working week was fairly similar between the US and the UK. American manufacturing wage-earners worked, on average, 1 additional hour per week compared to the British wage earners. The relative gap in the annual hours of work is slightly larger as a result of the greater number of vacation and holidays in the UK.

Table 2.12 presents the labor productivity statistics on a person-hour basis. The industry-specific employment data have been multiplied by the data on annual hours of work taken from table 2.11. Given the comparable length of the average working

92. Great Britain Department of Employment and Productivity, *British Labour Statistics: Historical Abstract 1886–1968* (London: H.M. Stationery Office, 1971), 95. Note that I assumed the average length of the working week to remain unchanged between 1906 and 1907.

93. United States Department of Commerce: Bureau of the Census, "Manufactures," 316–9; E. Jones, "New Estimates of Hours of Work per Week and Hourly Earnings, 1900–1957," *Review of Economics and Statistics* 45 (1963): 375.

94. R. Matthews, C. Feinstein, and J. Odling-Smee, *British Economic Growth, 1856–1973* (Oxford: Clarendon Press, 1982), 566; M. Huberman and C. Minns, "The Times They are not Changin': Days and Hours of Work in Old and New Worlds, 1870–2000," *Explorations in Economic History* 44 (2007): 546.

Table 2.12: Real value added per worker and per hour in manufacturing, US and UK (1909/07)

branch/sector	*value added per worker (% US/UK)*	*value added per hour (% US/UK)*
Food, drink and tobacco	155	151
Textile, apparel and leather	184	180
Chemicals, petroleum and rubber	176	162
Metal industries	224	211
Engineering and transport eq.	268	258
Miscellaneous	239	232
Manufacturing	214	207

Source: see tables 2.10 and 2.11.

week in the UK and the US, the hourly productivity estimates do not deviate much from the per worker figures. The hour-adjusted figures indicate that overall manufacturing productivity in the US stood at ca. 207 percent of the UK level, approximately 7 percentage points below the per worker estimate. At the detailed industry level, the drop in measured labor productivity ranged from 4 percentage points (food, drink and tobacco) to 14 percentage points (chemicals, petroleum and rubber). Overall, the per hour figures confirm the existence of a large transatlantic productivity gap in manufacturing, in the order of approximately 2:1, at the start of the twentieth century.

2.5 Total economy

In order to assess the impact of the new sectoral benchmarks on the overall productivity levels of the two countries, table 2.13 presents the reconciliation of comparative GDP per worker and per capita for the US and the UK. As a first step in the output based estimate of comparative productivity, I calculated a PPP deflator at the total economy level. This PPP is a weighted average of the value added PPPs for the agricultural, mining and manufacturing sectors listed in table 2.4, supplemented with implicit price deflators for the construction and service sectors. The latter are based on the comparative productivity estimates for these two sectors by Broadberry and Irwin which, when combined with the nominal value added per worker data listed in table 2.13, yield the comparative price levels at the sectoral level.[95]

The PPP for total economy, at 6.14 $/£, comes out considerably higher than the

95. Broadberry and Irwin, "Labor Productivity in the United States and the United Kingdom," 261.

Table 2.13: Comparative labor productivity and income, US and UK (1909/07)

	employment shares (%)		PPP[c]	value added per worker/capita		
branch/sector	*US*[a]	*UK*[b]	*($/£)*	*US ($)*[d]	*UK (£)*[e]	*US/UK*[f]
Agriculture	32.8	11.8	4.2	488	64	181
Industry	29.1	43.5	5.6	1,026	89	206
Mining	3.0	6.3	3.0	860	110	263
Manufacturing	21.3	32.1	5.7	1,063	86	214
Construction	4.8	5.1	*9.1*	970	80	*134*
Services	38.0	44.7	*7.2*	1,137	132	*119*
GDP per worker[g]	100.0	100.0	6.1	892	105	138
GDP per capita[h]			6.1	354	46	126

[a] *Source:* J. Kendrick, *Productivity Trends in the United States* (Princeton: National Bureau Economic Research, 1961), 296–7, 308; S. Lebergott, *Manpower in Economic Growth: The American Record Since 1800* (New York: McGraw-Hill, 1964), 118.

[b] *Source:* C. Feinstein, *Statistical Tables of National Income, Expenditure and Output of the UK, 1855–1965* (Cambridge: Cambridge University Press, 1976), 131.

[c] Fisher value added PPPs from table 2.4. PPPs in italics were derived implicitly from the value added per worker figures in the last three columns of this table.

[d] *Source:* S. Carter et al., eds., *Historical Statistics of the United States: Millennial Edition* (Cambridge: Cambridge University Press, 2006); W. King, *The National Income and Its Purchasing Power* (New York: National Bureau Economic Analysis, 1930); S. Fabricant, *The Output of Manufacturing Industries, 1899–1937* (New York: National Bureau Economic Analysis, 1940).

[e] *Source:* C. Feinstein, *National Income, Expenditure and Output of the United Kingdom, 1855–1965* (Cambridge: Cambridge University Press, 1972), 208.

[f] Double deflated value added per worker estimates from table 2.5. Productivity figures in italics were taken from S. Broadberry and D. Irwin, "Labor Productivity in the United States and the United Kingdom During the Nineteenth Century," *Explorations in Economic History* 43 (2006): 261.

[g] *Source:* C. Feinstein, *Statistical Tables of National Income, Expenditure and Output of the UK, 1855–1965* (Cambridge: Cambridge University Press, 1976), T10, T125–6; Kendrick, *Productivity trends in the United States*, 296–7, 308; S. Lebergott, *Manpower in Economic Growth: The American Record Since 1800* (New York: McGraw-Hill, 1964), 118.

[h] Population figures from A. Maddison, "Historical Statistics of the World Economy, 1–2008 AD," Groningen Growth & Development Centre, 2008.

official exchange rate which, in 1909, stood at 4.87 $/£.[96] In a study of the relative cost of living in Britain and the US, Williamson obtains a fairly similar PPP of 6.48 $/£, however.[97] This PPP, based on the relative prices of primarily food stuffs and rents, appears to corroborate the finding of a comparatively high American price level.

On the basis of the estimates of GDP at factor costs and total employment, the total economy PPP can be utilized to compare output per worker between the two countries. As shown in table 2.13, I find a US GDP per worker level of about 138 percent of the UK. This is nearly 10 percent above the original industry-of-origin estimate by Broadberry and Irwin – who value the American output per worker at 125 percent of the British level.[98] The new estimate puts the US comfortably in the lead in terms of total economy labor productivity at the start of the twentieth century.

As noted by Broadberry, "the aggregate comparative level of labor productivity at a point in time is the result not only of the levels of comparative labor productivity in each sector but also of differences in the structure of employment."[99] Table 2.13 shows that a large share of the American labor force was engaged in agriculture, while in the UK the labor force was concentrated in the high value-added service sectors. These structural differences provided the UK with a notable advantage – as value added per worker was substantially lower in agriculture than in industry or services – helping to explain the relatively modest lead in GDP per worker despite the large US/UK productivity gap in agriculture and industry.[100] Had the structure of the labor force been identical between the US and the UK at the start of the twentieth century, then the level of US output per worker would have been 150 or 157 percent of the British level – depending on whether the US or UK employment shares from table 2.13 are applied.

On the basis of Maddison's figures for the 1909 American and 1907 British population, an estimate of comparative GDP per capita can also be derived.[101] Table 2.14 compares this estimate with previous attempts to measure economy-wide income differences between the two countries. My industry-of-origin estimate is set against the expenditure-based productivity calculations by Ward and Devereux, the estimates by Broadberry and Irwin, and various versions of the Maddison data-set expressed in

96. Svennilson, *Growth and Stagnation in the European Economy*, 318–9.
97. J. Williamson, "The Evolution of Global Labor Markets Since 1830: Background Evidence and Hypotheses," *Explorations in Economic History* 32 (1995): 184.
98. Broadberry and Irwin, "Labor Productivity in the United States and the United Kingdom," 261.
99. Broadberry, "How Did the United States and Germany Overtake Britain?," 386.
100. Broadberry and Irwin, "Labor Productivity in the United States and the United Kingdom," 263.
101. Note that the GDP per capita figures are based on the estimates of GDP at factor costs and PPP deflator listed in table 2.13.

Table 2.14: Different approaches to estimate comparative GDP per capita, US and UK (ca. 1910)

author	*approach*	*year*	*rel. GDP p. capita (UK=100)*
This study	ICOP	1909/07	126
Ward & Devereux	Expenditure	1905	122
Broadberry & Irwin	Quantity relatives	1909/11	113
Broadberry & Irwin	Expenditure	1909/11	105
Maddison	1990 GK$	1910	108
Maddison	1985 GK$	1910	125
Maddison	1970 GK$	1910	127

Source: M. Ward and J. Devereux, "Measuring British Decline: Direct Versus Long-Span Income Measures," *Journal of Economic History* 63 (2003): 826–851; M. Ward and J. Devereux, "New Perspectives on International Standards of Living in the Late Nineteenth Century," in *XIV International Economic History Congress* (Helsinki, 2006), 1–28; S. Broadberry and D. Irwin, "Labor Productivity in the United States and the United Kingdom During the Nineteenth Century," *Explorations in Economic History* 43 (2006): 257–279; A. Maddison, *The World Economy: A Millennial Perspective* (Paris: Organisation for Economic Cooperation & Development, 2001); A. Maddison, *Dynamic Forces in Capitalist Development* (Oxford: Oxford University Press, 1991); A. Maddison, *Phases of Capitalist Development* (Oxford: Oxford University Press, 1982).

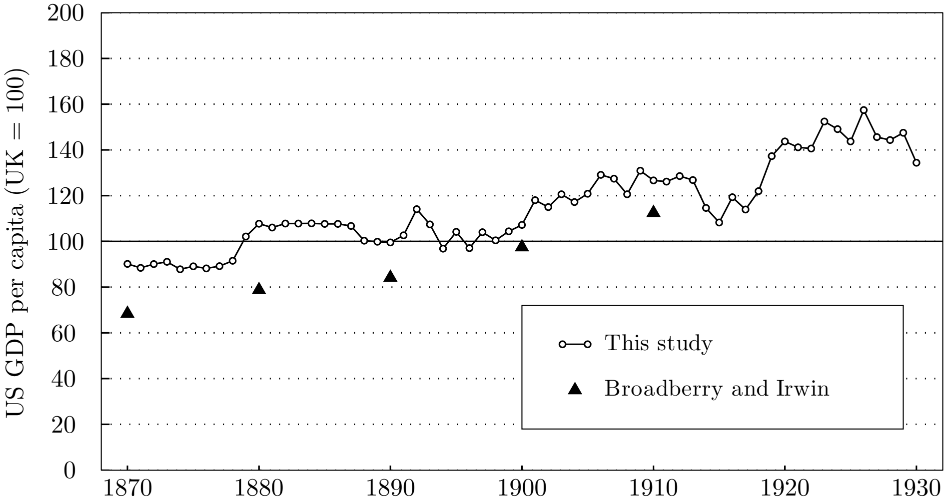
1970, 1985 and 1990 international Geary-Khamis dollars respectively.[102]

Overall, my Anglo-American GDP per capita estimate is higher than the figures suggested by Broadberry and Maddison. I appraise the American relative income per capita level to be 126 percent of the UK, which is actually very close to the figures provided by Ward and Devereux. It is interesting to note that my estimate also approximates the earlier estimates by Maddison, expressed in 1985 or 1970 dollars. This similarity seems to suggest that the earlier benchmarks of international dollars reflect the actual price differences around 1910 better than the later benchmarks, backing up earlier claims in this respect by Prados de la Escosura.[103]

A backward projection of my benchmark estimates on existing time-series again yield some interesting conclusions. Figure 2.1 summarizes the main findings of the changes in relative income levels. For the time series I rely on figures by Maddison, allowing me to compare the extrapolated GDP per capita figures against the Anglo-American comparative per capita income figures by Broadberry and Irwin.[104]

102. Ward and Devereux, "Measuring British Decline"; M. Ward and J. Devereux, "New Perspectives on International Standards of Living in the Late Nineteenth Century," in *XIV International Economic History Congress* (Helsinki, 2006), 1–28; Broadberry and Irwin, "Labor Productivity in the United States and the United Kingdom"; Maddison, *The World Economy*; Maddison, *Dynamic Forces in capitalist development*; Maddison, *Phases of Capitalist Development*.
103. Prados de la Escosura, "International Comparisons of Real Product."
104. Broadberry and Irwin, "Labor Productivity in the United States and the United Kingdom," 261; Maddison, "Historical Statistics of the World Economy: 1–2008 AD."

Figure 2.1: Comparative GDP per capita, US and UK (UK=100, 1870–1930)



Source: Benchmark 1909/07 based on double deflated estimate listed in table 2.13. Time series output and population, see A. Maddison, "Historical Statistics of the World Economy, 1–2008 AD," Groningen Growth & Development Centre, 2008; Broadberry and Irwin time series comparative per capita income, see S. Broadberry and D. Irwin, "Labor Productivity in the United States and the United Kingdom During the Nineteenth Century," *Explorations in Economic History* 43 (2006): 270.

The estimates by Broadberry and Irwin show a substantial British lead in per capita income terms between 1870 and 1890. According to their estimates, the US overtook the UK in GDP per capita not until 1910.[105] My benchmark extrapolation dates the overtaking considerably earlier. I find that around 1870 the UK enjoyed a small lead in per capita income terms. By 1880 this lead had dissipated and between 1880 to 1900 the US level of GDP per capita remained roughly on par with the UK. During the first three decades of the twentieth century, however, the US charged ahead and the income gap widened to nearly 60 percent in the 1920s.

Even though my new estimate of relative GDP per capita is very similar to the early twentieth century benchmark by Ward and Devereux (see table 2.14), the long-run trend illustrated in figure 2.1 does not correspond well to their nineteenth century expenditure benchmarks. As noted in section 2.1, Ward and Devereux show the US leading in terms of income per capita as early as 1872. In addition, they estimate a considerable gap in relative income levels between the US and the UK throughout the 1872–1905 period. On the basis of the new industry-of-origin benchmark and time-series evidence, I come to the conclusion that this appears to overstate the actual relative American income level in comparison to the UK. Still, the 1909/07 benchmark confirms the existence of a large gap in comparative productivity between the US and

105. Broadberry and Irwin, "Labor Productivity in the United States and the United Kingdom," 269.

the UK in agriculture and industry and provides strong evidence for a sizable American advantage in terms of GDP per worker and GDP per capita at the start of the twentieth century.

2.6 Conclusion

This study offers a new benchmark for agriculture, mining and five manufacturing branches in the US and the UK around 1910. On the basis of the ICOP approach, I measure the value of net output by industry translated to a common currency on the basis of sector-specific double deflated PPPs. This procedure takes both the differences in the relative prices of outputs as well as inputs into account, which proved to be of particularly importance for the productivity estimate of the manufacturing sector. In this sector I observe a notable gap in the relative PPPs for inputs and outputs, reflecting the American access to cheap intermediate inputs flowing from the agricultural and mining sectors.

The new benchmark estimates confirm the existence of a large transatlantic productivity gap in manufacturing, supporting earlier claims to this effect by Rostas and Broadberry. Contrary to the consensus view, however, I demonstrate that the Atlantic productivity gap in the early twentieth century extended to mining and agricultural sectors as well. Industrial productivity in the US stood at ca. 206 percent of the UK level, while American agriculture maintained a lead of 181 percent against its British counterpart. I show that American farmers took full advantage of labor-saving technologies, greatly improving their productivity level in comparison to the British farmers who focused instead on the saving of land. In similar vein, productivity in British mining was hampered by the relative hesitant introduction of technological improvements and unfavorable geological conditions.

The substantial US lead in agriculture and industry provides firm evidence for a strong overall lead in total economy productivity. However, as argued by Broadberry, differences in the employment structure between both economies did play a role in the relative income and productivity differentials. The low share of British employees in the agricultural sector provided Britain with a structural advantage that substantially reduced the gap in the overall level of productivity between the US and the UK. Applying the new benchmark estimates for ca. 1910 to long term projections of value added and total population back into the nineteenth century reveals an interesting new perspective on the dynamics of comparative long-term economic development, suggesting an earlier American takeover in terms of GDP per capita.

Rather than offering any definitive answers to the questions of long run economic growth and dynamics, my new benchmark estimate serves as a starting point for further investigations based on an industry-of-origin approach. A lot of work remains to be done on improving the quality of time-series of gross output, value added and employment for the nineteenth century, and in many cases the early twentieth century as well. In addition, expanding and improving estimates of service sector productivity is crucial to arrive at a more complete picture of convergence and divergence of income and productivity levels since the industrial revolution.

2.A Benchmark methods compared

Although the basic concepts behind the available industry-of-origin benchmark techniques are similar, there are some marked differences between the ICOP approach, used in this chapter, and Rostas' quantity approach. In this section, I discuss both the basic methodology behind the quantity approach and provide an in-depth discussion of the methodological similarities and differences between both approaches. Below, I show that the quantity approach can be rewritten to approximate a basic version of the unit value approach. I will also show, however, that in practice the outcomes of these methods can deviate substantially. Particularly the necessity to assign labor to individual commodities instead of industries within the quantity approach, limits this methodology's ability to estimate productivity for industries producing a wide array of heterogeneous products. I demonstrate the basic methodology on the basis of a simple single industry, two country, k product framework.

Rostas' quantity approach

In the quantity approach, labor productivity (lp_{ij}) for product i of country j, is defined as the ratio between the physical quantity produced (q_{ij}) and the employment used to produce this particular commodity (emp_{ij}).

$$lp_{ij} = \frac{q_{ij}}{emp_{ij}} \tag{2.13}$$

Unfortunately, employment at the commodity level is rarely available in historical sources. Broadberry shows that when quantity data is not available for the whole output of the trade, the estimate of operatives in the trade (emp_j) can be reduced in proportion to the ratio of the value of covered items (v_{ij}) to the value of total gross output (go_j), as shown in equation (2.14).[106]

$$emp_{ij} = emp_j \cdot \frac{v_{ij}}{go_j} \tag{2.14}$$

The comparative labor productivity ratio, LP_{io}, can then be obtained by dividing labor productivity of country n by the labor productivity of country o. In equation (2.15), the subscript n represents the numerator country, whereas the subscript o represents

106. Broadberry, "Comparative Productivity in British and American Manufacturing," 523; Rostas, *Comparative Productivity in British and American Industry*, 19–20.

the base country.[107]

$$
\begin{aligned}
LP_{io} &= \frac{lp_{in}}{lp_{io}} && (2.15)\\
&= \frac{q_{in}}{emp_n \cdot \frac{p_{in} \cdot q_{in}}{go_n}} \Big/ \frac{q_{io}}{emp_o \cdot \frac{p_{io} \cdot q_{io}}{go_o}}\\
&= \frac{go_n}{emp_n \cdot p_{in}} \Big/ \frac{go_o}{emp_o \cdot p_{io}}\\
&= \frac{go_n/emp_n}{go_o/emp_o} \Big/ \frac{p_{in}}{p_{io}}
\end{aligned}
$$

Substituting equation (2.14) into (2.13) – for both country n and o – in the comparative labor productivity ratio above, reveals that the outcome for the quantity approach is identical to the ratio of single deflated gross output per worker for both countries. In the case of a single commodity, the price deflator is given by the unit value ratio for this commodity. The *uvr* from equation (2.2) is used to transform either countries' gross output into the other countries' currency, making productivity in both countries directly comparable.

In the case when there are multiple clearly distinct products being produced in the same trade, the quantity output of these products can be weighted according to their relative prices. Broadberry provides an example of this procedure for the comparison of productivity in the American and British automobile, cycle and motorcycle industries.[108] He shows that the heterogeneous output of this industry (i.e. automobiles, cycles and motorcycles) can be converted to automobile equivalents using the relative unit values for either the US or the UK. Equation (2.16) illustrates this step on the basis of country o's relative prices.

$$
Q_{j(o)} = \frac{\sum p_{io} \cdot q_{ij}}{p_{1o}} \qquad (2.16)
$$

The outcome of equation (2.16) above, represents the sum of the output of k products for country j, expressed in quantities of the base product 1 (e.g. automobiles, as in Broadberry's example).[109] This aggregate quantity, $Q_{j(o)}$, can in turn be used to estimate comparative labor productivity for the entire industry; see equation (2.17). Note that the estimate of operatives in the industry (emp_j) is now reduced in proportion to

107. Note that the total production value of commodity i (v_{ij}) is, by definition, equal to the physical quantity produced (q_{ij}) times the unit value (p_{ij}) of this product.

108. Broadberry, "Comparative Productivity in British and American Manufacturing," 525–6; Rostas, *Comparative Productivity in British and American Industry*, 18–9.

109. Note that, for the calculation of the labor productivity ratios in (2.17) and (2.19), the choice of base product is irrelevant as it cancels out in the equation.

the ratio of the total value of all covered items ($\sum p_{ij} \cdot q_{ij}$) to the value of gross output (go_j).

$$LP_{o(o)} = \frac{\frac{\sum p_{io} \cdot q_{in}}{p_{1o}}}{emp_n \cdot \frac{\sum p_{in} \cdot q_{in}}{go_n}} \Big/ \frac{\frac{\sum p_{io} \cdot q_{io}}{p_{1o}}}{emp_o \cdot \frac{\sum p_{io} \cdot q_{io}}{go_o}} = \frac{go_n/emp_n}{go_o/emp_o} \cdot \frac{\sum p_{io} \cdot q_{in}}{\sum p_{in} \cdot q_{in}} = \frac{go_n/emp_n}{go_o/emp_o} / P^{go} \tag{2.17}$$

Rearranging the terms in equation (2.17) shows that the resulting productivity estimate will still be identical to the single deflated gross output per worker, only now using the Paasche gross output PPP (P^{go}) from section 2.2 as deflator. If I rely on the relative prices of country n instead, I obtain the aggregate quantity, $Q_{j(n)}$, which in turn translates into the comparative productivity ratio given in equation (2.19). This productivity estimate is still equivalent to single deflated gross output per worker, now using the Laspeyres gross output PPP (L^{go}) from equation (2.3) as the price deflator.

$$Q_{j(n)} = \frac{\sum p_{in} \cdot q_{ij}}{p_{1n}} \tag{2.18}$$

$$LP_{o(n)} = \frac{\frac{\sum p_{in} \cdot q_{in}}{p_{1n}}}{emp_n \cdot \frac{\sum p_{in} \cdot q_{in}}{go_n}} \Big/ \frac{\frac{\sum p_{in} \cdot q_{io}}{p_{1n}}}{emp_o \cdot \frac{\sum p_{io} \cdot q_{io}}{go_o}} = \frac{go_n/emp_n}{go_o/emp_o} \cdot \frac{\sum p_{io} \cdot q_{io}}{\sum p_{in} \cdot q_{io}} = \frac{go_n/emp_n}{go_o/emp_o} / L^{go} \tag{2.19}$$

Broadberry shows that, in line with the ICOP approach, the geometric average of these two estimates is taken as the overall productivity estimate in the quantity approach – thus reflecting both the relative prices of the numerator country n as well as the base country o.[110] Equation (2.20) illustrates that this is equivalent to the Fisher

110. Broadberry, “Comparative Productivity in British and American Manufacturing,” 525.

deflated ratio of gross output per worker.

$$\begin{aligned} LP_o &= \sqrt{LP_{o(o)} \cdot LP_{o(n)}} \\ &= \frac{go_n/emp_n}{go_o/emp_o} / \sqrt{L^{go} \cdot P^{go}} \\ &= \frac{go_n/emp_n}{go_o/emp_o} / F^{go} \end{aligned} \tag{2.20}$$

The ICOP versus the quantity approach

As illustrated above, the comparative labor productivity estimates at the industry level based on the quantity approach will be identical to those based on single deflated gross output, provided that employment at the commodity level is estimated according to equation (2.14). For his 1907/09 benchmark of Anglo-American manufacturing productivity – the study against which I contrast my own findings – Broadberry applies this method throughout, making his estimates directly comparable to the single deflated productivity ratios reported in table 2.10.[111]

In section 2.4, I show that Broadberry's quantity based estimates do in fact differ from my own single deflated figures, however. These differences stem primarily from the increased coverage of this study, both with respect to the products matched as well as the number of industries incorporated into the productivity comparison. For the manufacturing sector, Broadberry directly compared 35 different products between both countries.[112] In contrast, I matched a total of 111 products, considerably broadening the range of products covered and taking important variations in the quality of goods into account.[113] As noted in section 2.4, this underscores one of the drawbacks of the quantity approach. The assignment of labor used to produce a single good is economically less sensible when the share of output for that good only comprises a small fraction of the total production value in that industry. Consequently, this limits the quantity approach's ability to estimate productivity for industries producing a wide array of heterogeneous products.[114]

In addition, I base my productivity results on the total gross output (or net output) and employment for the entire manufacturing sector. I implicitly assume that the relative price ratios are representative conversion factors for both the industries for which products were covered as well as those for which no matches could be made. Broadberry does not make this assumption, and his productivity estimates are based on 29

111. Broadberry, "Comparative Productivity in British and American Manufacturing," 538–45; see also, Broadberry, "Forging Ahead, Falling Behind and Cathing-Up," 27.
112. Broadberry, "Comparative Productivity in British and American Manufacturing," 538–45.
113. See table 2.3 and appendix 2.B for further details.
114. Rostas, *Comparative Productivity in British and American Industry*, 12–4.

industries covering 42 percent of British and 37 percent of American employment. Although, both approaches have their merits, the complete inclusion of all manufacturing industries does impact the productivity estimates.

Furthermore, the ICOP framework allows for several extensions which serve to improve the quality of the international benchmark estimates. The primary extension is the use of value added and the application of the double deflation technique. As illustrated above, the quantity approach relies on gross output as a measure of output in labor productivity, whereas modern international comparisons generally opt for value added.[115] This is of importance particularly when the ratio of intermediate inputs to gross output varies between countries as well as industries. As noted in the main text, these variations can occur as a result of differences in production methods, the types of materials used, and the amount of imported materials, but can also be caused by differences in industry classifications between the countries under comparison.[116] In addition, I apply the double deflation technique, which does not only take relative prices for gross output into account, but also compensates for relative price differentials for intermediate inputs.[117] Double deflation is generally considered to be the preferred approach for sector comparisons of output and productivity, and recent studies have shown that this adjustment could be of particular importance for benchmark studies that examine the turbulent interwar years.[118] As governments put in place increasingly restrictive foreign trade regimes and tight currency controls during this period, the internal price level and ratios between input and output prices tended to deviate substantially.[119]

Another extension to the ICOP framework is the stratified sampling approach, which introduces an alternative weighting scheme. The stratified sampling theory proposes that the process of aggregation of the relative price ratios can be made more precise if a heterogeneous population (the products matched) is divided into more homogeneous sub-populations, referred to as strata. These strata usually take the form of industries, the output of which can be used as alternative weights to aggregate the price ratios. For an elaborate description of the stratified sampling theory see the work of Timmer.[120]

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115. Paige and Bombach, *A Comparison of National Output and Productivity*; Maddison and Ark, "Comparison of Real Output in Manufacturing"; Ark, *International Comparisons of Output and Productivity*.
116. Fremdling, Jong, and Timmer, "British and German Manufacturing Productivity Compared," 360.
117. Paige and Bombach, *A Comparison of National Output and Productivity*, 82.
118. Fremdling, Jong, and Timmer, "British and German Manufacturing Productivity Compared."
119. ibid., 352.
120. M. Timmer, "On the Reliability of Unit Value Ratios in International Comparisons," *Groningen Growth and Development Centre Memorandum* 31 (1996): 1–31; M. Timmer, *The Dynamics of Asian Manufacturing: A Comparative Perspective in the Late Twentieth Century* (Cheltenham: Edward Elgar Publishing, 2000), 21.

2.B Output unit value ratios

Table 2.15: Output UVRs, US and UK (1909/07)

description	quantity unit	United States quantity (x,000)	United States value ($,000)	United Kingdom quantity (x,000)	United Kingdom value (£,000)	uvr ($/£)
Wheat	Cubic meters	24,081	657,657	1,911	10,370	5.0
Barley	Cubic meters	6,108	92,459	1,990	9,177	3.3
Oats	Cubic meters	35,491	414,697	4,496	13,264	4.0
Rye	Cubic meters	1,040	20,422	72	220	6.4
Beans	Cubic meters	396	21,771	338	1,735	10.7
Peas	Cubic meters	251	10,964	223	1,130	8.6
Buckwheat	Cubic meters	523	9,331	4	22	3.1
Hay	Tons (metric)	62,444	685,042	9,876	31,818	3.4
Potatoes	Tons (metric)	9,709	166,424	3,981	9,892	6.9
Hops	Tons (metric)	18	7,845	24	1,059	9.6
Straw	Tons (metric)	507	3,280	7,112	12,660	3.6
Strawberries	Tons (metric)	145	17,914	42	1,036	5.0
Raspberries	Tons (metric)	35	5,132	10	309	5.0
Currants	Tons (metric)	6	790	6	153	5.5
Gooseberries	Tons (metric)	3	417	18	208	11.8
Other small fruit	Tons (metric)	53	5,721	13	252	5.4
Apples	Tons (metric)	3,181	83,231	228	1,490	4.0
Pears	Tons (metric)	196	7,911	9	90	4.2
Cherries	Tons (metric)	75	7,231	9	194	4.5
Plums	Tons (metric)	393	10,299	36	357	2.7
Milk: farm	Liters (x000)	22,007	757,562	5,492	35,274	5.4
Butter: farm	Tons (metric)	451	222,861	25	2,940	4.2
Cheese: farm	Tons (metric)	4	1,142	25	1,400	4.9
Eggs: farm	Dozens	1,591,311	306,689	92,374	3,772	4.7
Horses	Number	1,768	210,264	53	1,590	4.0
Meat: cattle and calves	Tons (metric)	3,635	710,015	482	27,264	3.5
Meat: sheep	Tons (metric)	287	67,073	265	18,169	3.4
Meat: pigs	Tons (metric)	3,898	717,674	321	14,362	4.1
Wool: unprocessed	Tons (metric)	131	65,472	40	2,600	7.7
Coal: anthracite	Tons (metric)	73,536	149,416	3,972	2,297	3.5
Coal: bituminous	Tons (metric)	344,498	405,487	266,864	117,256	2.7
Iron pyrite	Tons (metric)	251	1,028	11	5	9.2
Petroleum	Liters (x000)	28,957	128,249	179	357	2.2
Iron ore	Tons (metric)	51,332	106,540	15,226	4,315	7.3
Gypsum	Tons (metric)	2,044	5,907	205	98	6.0
Arsenic oxides	Tons (metric)	1	53	4	41	4.8
Salt: unrefined	Tons (metric)	3,825	8,344	1,264	576	4.8
Sand	Tons (metric)	53,035	17,174	1,977	165	3.9
Barytes	Tons (metric)	53	199	35	43	3.0
Coke	Tons (metric)	35,666	89,965	11,526	9,516	3.1
Coke breeze	Tons (metric)	1,489	5,723	7,706	4,434	6.7
Tar	Tons (metric)	604	3,284	787	767	5.6
Cotton: yarn	Tons (metric)	230	132,249	675	78,304	4.9
Cotton: piece goods	Sq. meters	5,280,169	443,163	5,869,387	81,313	6.1
Cotton: waste	Tons (metric)	141	10,874	195	3,749	4.0
Wool: tops	Tons (metric)	5	8,027	26	4,751	8.6
Wool: noils	Tons (metric)	12	8,939	8	866	6.5
Wool: waste	Tons (metric)	11	3,525	13	746	5.4
Wool: shoddy and mungo	Tons (metric)	22	5,699	58	1,859	8.1
Wool: yarns worsted	Tons (metric)	42	83,918	72	17,524	8.2
Wool: yarns woollen	Tons (metric)	18	9,649	18	2,150	4.5
Wool: flannels	Sq. meters	17,219	4,390	40,530	1,774	5.8
Wool: carpets	Sq. meters	47,807	48,476	21,490	3,251	6.7
Wool: rugs	Sq. meters	20,102	18,490	3,182	638	4.6

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Table 2.15 - continued from previous page

desc	unit	us_q	us_v	uk_q	uk_v	uvr
Wool: woollen tissues	Sq. meters	412,078	271,013	196,733	24,403	5.3
Jute: yarns	Tons (metric)	28	4,362	138	4,022	5.3
Jute: piece goods	Sq. meters	59,798	4,057	218,450	3,579	4.1
Hemp: yarns	Tons (metric)	2	983	7	375	7.4
Hosiery: hose, half-hose	Pairs	748,688	65,121	172,668	4,402	3.4
Cordage, cables, ropes and twine	Tons (metric)	419	76,295	106	4,701	4.1
Skins: fellmongery	Number	97,681	75,648	9,831	996	7.6
Skins: tanned	Number	67,572	53,119	186,344	14,688	10.0
Gloves: leather	Dozen Pairs	40,424	22,526	7,020	839	4.7
Boots and shoes: leather	Pairs	247,643	442,631	97,984	20,066	8.7
Hats: felt	Number	40,267	46,146	18,888	2,491	8.7
Shawls	Number	2,627	916	1,219	238	1.8
Pig iron	Tons (metric)	26,063	387,830	10,276	33,304	4.6
Steel: ingots	Tons (metric)	129	3,594	6,627	29,740	6.2
Iron and steel: bars, rods and structural shapes	Tons (metric)	5,533	192,642	3,283	24,246	4.7
Iron and steel: rails	Tons (metric)	2,690	77,811	970	5,638	5.0
Iron and steel: plates and sheets	Tons (metric)	3,023	133,272	1,639	11,977	6.0
Iron and steel: armor plates	Tons (metric)	24	10,649	18	1,771	4.5
Iron and steel: hoops and strips	Tons (metric)	309	10,430	396	3,045	4.4
Iron and steel: pipes and fittings, cast	Tons (metric)	1,891	64,515	347	2,013	5.9
Iron and steel: tires and axles	Tons (metric)	93	3,831	139	1,910	3.0
Iron and steel: scrap metal	Tons (metric)	1,124	18,164	710	2,231	5.1
Iron and steel: blooms, billets and slabs	Tons (metric)	4,511	110,762	609	3,376	4.4
Steel: sheets and tinplate bars	Tons (metric)	1,499	37,745	1,007	5,308	4.8
Tinplate: tinplate and terneplate	Tons (metric)	597	45,815	537	7,402	5.6
Tinplate: black plates and sheets	Tons (metric)	573	30,956	145	1,343	5.8
Iron and steel: pipes and fittings, wrought	Tons (metric)	1,578	90,622	309	6,090	2.9
Iron and steel: wire rods	Tons (metric)	2,082	61,948	119	882	4.0
Iron and steel: wire	Tons (metric)	1,043	52,727	189	2,801	3.4
Iron and steel: nails	Tons (metric)	46	2,218	16	176	4.3
Iron and steel: wire nails and staples	Tons (metric)	657	28,900	5	55	3.7
Iron and steel: galvanized sheets	Tons (metric)	392	25,912	505	7,157	4.7
Bicycles	Number	168	2,388	624	3,441	2.6
Motor cycles	Number	19	3,016	4	139	4.4
Motor cars	Number	127	164,308	10	3,323	3.8
Vessels: wood and steel	Tonnage (gross)	467	37,680	1,614	24,178	5.4
Copper: ingots	Tons (metric)	496	142,084	42	3,422	3.5
Copper: plates, sheets, rods	Tons (metric)	138	40,916	51	4,881	3.1
Copper: wire	Tons (metric)	140	47,184	13	1,350	3.2
Brass: wire	Tons (metric)	16	5,580	3	218	4.2
Lead: pig	Tons (metric)	321	30,460	29	518	5.4
Tin: pig	Tons (metric)	0	16	13	2,177	4.0
Flour: wheat	Tons (metric)	10,497	557,815	4,037	43,139	5.0
Offals: wheat	Tons (metric)	3,788	91,407	1,959	8,694	5.4
Flour: barley, corn, buckwheat	Tons (metric)	2,972	117,213	1,459	11,100	5.2
Animal feed	Tons (metric)	5,444	164,735	150	1,006	4.5
Rice: cleaned	Tons (metric)	298	21,048	92	895	7.3
Pork: bacon	Tons (metric)	336	97,856	87	5,326	4.7
Pork: hams	Tons (metric)	358	101,089	23	1,663	3.9
Pork: salted	Tons (metric)	432	95,959	1	35	6.1

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Table 2.15 - continued from previous page

desc	*unit*	*us_q*	*us_v*	*uk_q*	*uk_v*	*uvr*
Lard	Tons (metric)	564	134,397	31	1,479	5.0
Butter: factory	Tons (metric)	186	115,098	56	5,840	5.9
Cheese: factory	Tons (metric)	139	42,435	4	193	6.0
Cream: factory	Tons (metric)	37	9,829	5	398	3.4
Margarine: factory	Tons (metric)	19	5,964	45	2,094	6.5
Ice	Tons (metric)	12,909	44,139	619	389	5.4
Sugar: refined	Tons (metric)	747	71,741	574	8,995	6.1
Molasses	Tons (metric)	249	3,975	56	303	3.0
Fish: cured	Tons (metric)	0	10	133	3,712	4.7
Cigars	Tons (metric)	64	193,807	2	1,146	4.5
Cigarettes	Tons (metric)	14	35,373	14	4,532	7.7
Manufactured tobacco	Tons (metric)	159	131,660	34	4,478	6.3
Acid: acetic	Tons (metric)	26	1,337	6	91	3.5
Acid: nitric	Tons (metric)	12	1,357	6	91	7.3
Acid: sulphuric	Tons (metric)	1,340	10,085	550	955	4.3
Sulphates: alum	Tons (metric)	33	654	73	213	6.7
Sulphates: ammonia	Tons (metric)	56	3,227	306	3,271	5.4
Bleaching materials	Tons (metric)	14	226	111	444	3.9
Borax	Tons (metric)	38	1,202	14	205	2.2
Essential oils	Tons (metric)	0	1,129	0	112	7.6
Soda compounds	Tons (metric)	842	17,270	693	3,317	4.3
Sulphur	Tons (metric)	260	4,605	31	148	3.8
Tallow and animal fat	Tons (metric)	117	20,372	56	1,459	6.7
Fertilizer: superphosphate	Tons (metric)	1,375	16,957	615	1,321	5.7
Fertilizer: other	Tons (metric)	3,379	75,413	520	2,353	4.9
Glue and gelatine	Tons (metric)	13	1,944	43	653	10.2
Soap: hard	Tons (metric)	802	89,830	302	7,266	4.7
Soap: soft	Tons (metric)	27	1,269	83	1,499	2.6
Glycerin	Tons (metric)	53	16,591	16	604	8.4
Paraffin wax	Tons (metric)	161	9,389	4	99	2.1
Seedcrushing	Tons (metric)	1,652	91,100	1,393	12,940	5.9
Hard wood: oak	Cubic meters	10,417	90,512	102	237	3.7
Hard wood: ash	Cubic meters	687	7,116	17	37	4.7
Hard wood: elm	Cubic meters	820	6,088	17	21	5.8
Paper: fine	Tons (metric)	172	29,079	120	3,059	6.7
Paper: printing	Tons (metric)	1,589	89,702	462	5,894	4.4
Paper: packing and wrapping	Tons (metric)	692	42,221	191	2,032	5.7
Paper: printed and coated	Tons (metric)	102	11,397	39	975	4.5
Paper: boards	Tons (metric)	801	29,498	54	626	3.2
Paper: other	Tons (metric)	15	1,736	14	440	3.9
Bricks	Thousands	12,473	94,993	4,760	6,329	5.7
Cement	Tons (metric)	13,407	68,752	2,923	3,439	4.4
Organs, reed	Number	64	2,595	4	30	5.8
Pianos	Number	331	46,188	58	972	8.3
Pianolas	Number	45	10,750	1	23	5.1

Chapter 3

Depression Dynamics

A New Estimate of the Anglo-American Manufacturing Productivity Gap in the Interwar Period*

3.1 Introduction

The large productivity lead that the US achieved over western Europe by the mid-twentieth century is one of the most characteristic long-term aspects of US economic development. Whether it was created by 'good fortune, Yankee ingenuity, or European stupidity', however, still remains an open question.[1] The present chapter contributes to the discussion of when and how manufacturing labor productivity in the US moved far ahead of the UK and of continental Europe.

From the statistical evidence collected by Broadberry, as well as that presented in the previous chapter, we know that the US/UK productivity gap of the order of 2:1 dates back to the mid-nineteenth century, and was carried over into the twentieth century.[2] However, according to Broadberry, there seems to be no clear trend in the movement of comparative performance: "US/UK comparative labor productivity in manufacturing over the whole period 1850–1989 is best described as stationary, exhibiting neither upward nor downward trend".[3] Deviations from this long-term equilibrium

∗. This chapter is an adapted version of H. de Jong and P. Woltjer, "Depression Dynamics: A New Estimate of the Anglo-American Manufacturing Productivity Gap in the Interwar Period," *Economic History Review* 64 (2011): 472–492.

1. L. Hannah, "Logistics, Market Size, and Giant Plants in the Early Twentieth Century: A Global View," *Journal of Economic History* 68 (2008): 74.

2. Broadberry, *The Productivity Race*, 3; see also Broadberry and Irwin, "Labor Productivity in the United States and the United Kingdom," 265.

3. Broadberry, *The Productivity Race*, 39. For the period after the Second World War Broadberry reported comparative US/UK levels of 2.5/1 until 1960, followed by a decline.

have been associated with the disruptions brought on by the two world wars. From his own figures Broadberry concluded that Britain and Germany failed to close the gap on the US in the interwar period; the gap widened during the 1920s, but was followed by a 'temporary cyclical narrowing' during the Great Depression.[4]

Recent studies, however, have emphasized the depression's contribution to growth of potential output in the US economy. Field has shown that US growth in the first part of the twentieth century was exceptionally high, in particular between 1929 and 1941.[5] In several publications he conjectures that the fastest productivity growth in the US took place across the depression years of the 1930s and not during the Second World War.[6] Between 1929 and 1941 total-factor productivity (TFP) in the non-farm economy grew at a rate of 2.3 percent per year, being the highest peak-to-peak rate of the century. Almost 50 percent of TFP growth originated from manufacturing. For the 1920s, he estimated that manufacturing's contribution was about 80 percent of a total TFP increase of 2.0 percent per year. During the interwar years, he suggests, the foundations were laid for much of the US productivity growth of the 1950s.[7] The Great Depression did not push down the underlying productivity trend of the US economy. Although Field conjectures that the gap with Europe widened further during the 1930s, he does not come forward with comparative evidence.[8] If we look at manufacturing alone, however, the much cited estimate by Broadberry claims a US/UK comparative productivity level on a per worker basis of 250 in 1929 and a level of 192 in 1938, which suggests a relative decrease in US comparative productivity.[9] This estimate sits uncomfortably with Field's revisionist account of US manufacturing productivity during the depression. Moreover, existing studies provide a rather bleak picture of British manufacturing performance during the 1930s. In the literature we find a critical account of the functioning of British capital markets, competition in product markets, and the effects of industrial relations, which were not very favorable for long-

4. Broadberry, *The Productivity Race*, 291. See also P. Temin, "The Golden Age of European Growth Reconsidered," *European Review of Economic History* 6 (2002): 12–9, which explains the fast post-1945 growth by pointing at an arrested development of structural change in many European countries between 1914 and 1945.

5. Field built on prior work by Gordon, who identified the 'one big wave' more generally with the second quarter of the twentieth century (1928–1950); R. Gordon, "US Economic Growth Since 1870: One Big Wave?," *American Economic Review* 89 (1999): 123–128; R. Gordon, "Interpreting the One Big Wave in US Long-term Productivity Growth," chap. 2 in *Productivity, Technology, and Economic Growth*, ed. B. van Ark, S. Kuipers, and G. Kuper (Dordrecht: Kluwer Academic Publishers, 2000), 60. See also Bernstein, *The Great Depression*, 121–43.

6. Field, "The Most Technologically Progressive Decade of the Century," 1399. For a treatment of the moderate supply-side effects of the war, see A. Field, "The Impact of the Second World War on US Productivity Growth," *Economic History Review* 61 (2008): 672–694.

7. Field, "Technological Change and US Productivity Growth," 205, 216, 228.

8. Field, "The Equipment Hypothesis and US Economic Growth," 49.

9. Broadberry, *The Productivity Race*, 48–9. See also S. Broadberry and N. Crafts, "Britain's Productivity Gap in the 1930s: Some Neglected Factors," *Journal of Economic History* 52 (1992): 532–3; they estimate TFP growth in the British economy at 1.9 percent per year between 1924 and 1937.

run productivity performance.[10] There was a shortfall on a broad front nurtured by a 'cozy collusive environment' that presumably differed a lot from the US competitive environment characterized by modern antitrust legislation.[11] Given the political and economic disarray of Europe between 1914 and 1945 and the apparent productivity growth realized in the US economy during this period, the alleged persistence of a nineteenth- and twentieth-century US/UK manufacturing productivity gap of 2:1 is clearly a subject that needs to be addressed.

The most important quantitative assessment of the comparative performance of the British and US economies in the 1930s is the widely used study by Rostas published in 1948.[12] Later studies of relative US/UK performance, including the quantitative assessment carried out by Broadberry and Crafts, rely heavily on Rostas's detailed study of physical output per worker, which is based on the manufacturing censuses of the UK (1935) and the US (1937/39).[13] We believe that this comparison needs to be revised and completed according to modern standards. The study by Rostas is based on only 31 industries, it uses physical output per worker as a measure of productivity performance instead of real value added per working hour, and it applies different census-reporting years between the UK and the US. Therefore it is hard to make the results of his comparisons consistent with the methods of historical national accounting that are applied today.

In the present study we introduce new methods of US/UK comparison and focus on one common census year for both countries, 1935, to guarantee complete and consistent coverage of all industries that were reported in the official censuses. We use real value added as the measure of output and productivity of industries, instead of 'traditional' indicators such as physical output per worker. We show that, aside from the construction of new comparative value added estimates, the adjustment for the variation in the interwar working week between the US and the UK is an important factor in reconciling the different positions in the US/UK productivity debate.

One of the central findings of this chapter is that the US/UK productivity gap during the 1930s was not stationary but became much wider than existing estimates show, once we adjust for hours worked. The new estimates display larger cross-industry variations in productivity levels than those resulting from Rostas's study, and present a clear picture of the key industries that were responsible for widening the gap between

10. N. Crafts, "Long-run Growth," chap. 1 in Floud and Johnson, *The Cambridge Economic History of Modern Britain*, 2:22.

11. Eichengreen, "The British Economy Between the Wars," 340. See A. Booth, "The Manufacturing Failure Hypothesis and the Performance of British Industry During the Long Boom," *Economic History Review* 56 (2003): 1–33 for a revisionist interpretation of UK manufacturing performance in the period immediately after the Second World War.

12. Rostas, *Comparative Productivity in British and American Industry*.

13. Broadberry and Crafts, "Britain's Productivity Gap in the 1930s," 543.

US and British manufacturing performance.

3.2 Data

The data for our benchmark comparison come from the official production censuses. For the UK we used the *Fifth Census of Production* of 1935, published by the Business Statistics Office (BSO) of the Board of Trade.[14] For the US we relied on the *Biennial Census of Manufactures* of 1935, published by the Bureau of the Census of the US Department of Commerce.[15] Both surveys contain detailed information on quantities and values of produced items, average prices, gross output, intermediate inputs, and employment. As the information for output and inputs is based on one and the same questionnaire – for which the information is supplied at the level of firms – internal consistency is guaranteed.[16]

Business cycle and capacity utilization effects may influence the results of measurement of output and productivity levels for one particular year. Rostas addressed this issue in his study of prewar British and US manufacturing and concluded that 1937 was the best year for comparison, as, at this point in time, the degree of capacity utilization was roughly similar in both economies.[17] However, data for manufacturing in the UK were not fully available for that year. The Import Duties Act Inquiry of 1937 does cover some of the manufacturing branches, but information for the majority of the manufacturing industries was not yet tabulated or published by the time Rostas started his study.[18] To overcome this problem he decided to compare the year 1935 for Britain with the year 1939 for the US, working back toward 1937. The primary reason why Rostas relied so heavily on the US 1939 *Biennial Census of Manufactures* and not the 1935 or 1937 census reports is that it met the sizable data requirements of the quantitative study he employed.[19]

We believe that for the purpose of the present comparison the 1935 censuses for the UK and the US are a good match. Both reports provide a systematic and detailed assessment of all manufacturing industries in the two countries. The British census distinguishes 108 manufacturing industries or trades, whereas the US census covers

14. Board of Trade, *Final Report on the Fifth Census of Production and the Import Duties Act Inquiry (1935)* (London: H.M. Stationery Office, 1938–44).

15. United States Department of Commerce: Bureau of the Census, *Biennial Census of Manufactures 1935* (Washington D.C.: United States Government Printing Office, 1938).

16. See Jong and Woltjer, "A Comparison of Real Output and Productivity," appendix A, for a discussion of the comparability of the British and US census reports.

17. Rostas, *Comparative Productivity in British and American Industry*, 24.

18. Board of Trade, *Preliminary Reports of the Import Duties Act Inquiry 1937* (London: H.M. Stationery Office, 1937–8).

19. This particular census is part of the 1940 decennial census and contains detailed figures on the size of plants, horse power of machinery installed, and so on. See United States Department of Commerce: Bureau of the Census, "Manufactures: Statistics by Subjects," in *Sixteenth Decennial Census of the United States*.

Table 3.1: Output, employment, and labor productivity in manufacturing, US and UK (1929–1937)

variables	*1929*	*1931*	*1933*	*1935*	*1937*
US output	100.0	72.0	62.8	82.8	103.3
UK output	100.0	89.2	96.3	114.6	132.9
US hours worked	100.0	63.1	53.8	64.8	79.4
UK hours worked	100.0	80.5	86.1	94.5	105.8
US productivity	100.0	114.1	116.8	127.9	130.1
UK productivity	100.0	110.8	111.8	121.3	125.6
Comparative US/UK productivity	100.0	102.9	104.4	105.4	103.6

Source: US output: J. Kendrick, *Productivity Trends in the United States* (Princeton: National Bureau Economic Research, 1961), 465–6, UK output: S. Broadberry, *The Productivity Race: British Manufacturing in International Perspective, 1850–1990* (Cambridge: Cambridge University Press, 1997), 42–5, US hours worked: J. Kendrick, *Productivity Trends in the United States* (Princeton: National Bureau Economic Research, 1961), 465–6. Annual average hours worked: E. Jones, "New Estimates of Hours of Work per Week and Hourly Earnings, 1900–1957," *Review of Economics and Statistics* 45 (1963): 375; M. Huberman and C. Minns, "The Times They are not Changin': Days and Hours of Work in Old and New Worlds, 1870–2000," *Explorations in Economic History* 44 (2007): 546–8. UK hours worked: S. Broadberry, *The Productivity Race: British Manufacturing in International Perspective, 1850–1990* (Cambridge: Cambridge University Press, 1997), 42–5. Annual average hours worked: M. Huberman and C. Minns, "The Times They are not Changin': Days and Hours of Work in Old and New Worlds, 1870–2000," *Explorations in Economic History* 44 (2007): 465–6; R. Hart, "Hours and Wages in the Depression: British Engineering 1926–1938," *Explorations in Economic History* 38 (2001): 7; C. Clark, *The Conditions of Economic Progress*, 2nd (London: MacMillan, 1951), 68; International Labour Office, *The ILO Year-book* (Geneva, 1931); International Labour Office, *Year Book of Labour Statistics 1939* (Geneva, 1939); International Labour Office, *Year Book of Labour Statistics 1962* (Geneva, 1962).

327 industries and sub-industries. We have reclassified the industries of both countries into 12 branches and 93 common industries, based on the classification of the UK census.[20]

Potential effects of the business cycle can be detected by making use of existing time series of output and employment (adjusted for hours worked) to calculate the average movement in productivity levels in the manufacturing sector for both countries. Table 3.1 shows the biennial movement of manufacturing output, employment and productivity in the 1930s.

During the first phase of the Great Depression, output in US manufacturing declined faster than in British manufacturing. Recovery in the US was much slower. In

20. The production censuses cover not only the entire manufacturing sector, but also contain data on mining, construction works, public utilities, and government industries. For the purpose of this study we excluded the latter industries and focused primarily on the manufacturing sector. See Jong and Woltjer, "A Comparison of Real Output and Productivity," appendix B, for a comparative overview of inputs and output of US and UK manufacturing industries in 1935.

both countries the drop in hourly employment was larger than the decline in output. Recovery of US manufacturing employment was also slower than in Britain. Labor productivity movements in both countries show an upward tendency throughout the 1930s. For the period 1929–1933 the observations seem to contradict the fact, observable in much empirical work, that average labor productivity is pro-cyclical. Still, we have to keep in mind that many of these studies refer to detrended measures of TFP for the whole economy and not to labor productivity within manufacturing.[21] Should we, nevertheless, accept the idea of pro-cyclical labor productivity, it would imply that the comparatively lower US capacity utilization (measured by employment levels) in our comparison year 1935 might be an indication of lower productivity outcomes relative to the UK. Measured productivity levels calculated from the census of 1935 may therefore underestimate potential output and thus productivity in the US vis-á-vis the UK for this particular year.[22] Note, however, that the year 1935 only shows a slightly different comparative ratio of US/UK productivity levels relative to other years. From these numbers we can conclude that the relative positions of 1935 manufacturing productivity levels in the business cycle do not reveal a substantial effect of capacity utilization differentials between the US and the UK.

3.3 Purchasing power parities

This section presents the method of comparison used in this study.[23] We calculated comparative levels of productivity by systematically measuring output and employment in each industry, which is also known as the industry-of-origin approach. Using this approach one can apply either the quantity or the value method. The first method was used by Rostas, who made direct comparisons of physical quantities of output (in tons, gallons, or units).[24] The second procedure measures the value of gross output and net output by industry (in national currency) which is then translated into a common currency with a sector-specific purchasing power parity (PPP). As Paige and Bombach have demonstrated in their US/UK comparison for the postwar period, suitable conversion factors can be obtained by constructing so-called industry-of-origin PPPs from either output price data alone (single deflation) or from price data for output as well

21. For a study of the British economy between 1871 and 1997, see J. Chadha and C. Nolan, "A Long View of the UK Business Cycle," *National Institute Economic Review* 182 (2002): 72–89. See Field, "The Procyclical Behavior of Total Factor Productivity in the United States," for a long-term study of the US economy. B. Bernanke and M. Parkinson, "Procyclical Labor Productivity and Competing Theories of the Business Cycle: Some Evidence From Interwar US Manufacturing Industries," *Journal of Political Economy* 99 (1991): 445, find pro-cyclical labor productivity for the interwar period in a sample of US industries, covering 20 percent of the manufacturing sector.

22. Broadberry and Crafts, "Britain's Productivity Gap in the 1930s," 542.

23. See chapter 2 for a detailed discussion of the ICOP approach.

24. Rostas, *Comparative Productivity in British and American Industry*.

as intermediate inputs (double deflation).[25] We used their method and calculated average factory gate prices from the values and quantities of the items reported in the official production censuses of both countries for the year 1935.

The first step in the calculation of the PPPs is the matching of products between the two countries. The level of detail of the census data with respect to output allowed us to match 359 products.[26] On the intermediate inputs side we could match 67 items.[27] An average value of a product or an intermediate input, the unit value (UV), reflects the domestic producer price of an item. Next, unit value ratios (UVRs) of identical products in both countries have been calculated and aggregated into a specific industry or branch PPP. With this PPP, output and intermediate inputs of the two countries were converted into a common currency.[28]

Table 3.2 features the Laspeyres, Paasche, and Fisher gross output PPPs per branch and for total manufacturing. These PPPs are based solely on output unit value ratios, aggregated to the branch and sector level using a stratified sampling approach.[29] For these bilateral comparisons the weights of either the base country (the UK) or the US can be used, which provide a Laspeyres and a Paasche type PPP, respectively. We used the geometric average of both indices, the Fisher index, as the currency conversion factor for our productivity comparisons, which is considered common practice in this type of research. The overall Fisher gross output PPP is 4.84 US dollars per pound sterling, which is very close to the official exchange rate of 4.94 \$/£. However, the large cross-industry variation of the output PPPs shows that the exchange rate would function poorly as a PPP on a sector level.

Direct quantity and price information for inputs is available for a wide range of industries in the British census, but in the US census it is available for textiles and iron and steel only. To acquire intermediate input PPPs for all branches within the manufacturing industry we applied a procedure that explicitly takes input-output relations into account. By definition inputs for one industry are made up of the output of another industry, meaning it is possible to derive an intermediate input PPP for an industry as a weighted set of output UVRs from the industries furnishing its inputs. We used the detailed US/UK output UVRs for all manufacturing output items, as described above, as the basis for our intermediate input PPPs. Next we applied weights that were constructed with information on the flow of goods between industries from

25. Paige and Bombach, *A Comparison of National Output and Productivity*.
26. See appendix 3.A for further details.
27. Intermediate inputs were covered for the textiles and iron and steel branches only; see appendix 3.B.
28. The methodology and formulas which we applied are similar to the procedures that were used in the study on British and German manufacturing by Fremdling, Jong, and Timmer, "British and German Manufacturing Productivity Compared," 375–6.
29. A detailed description of the stratified sampling approach is provided in Timmer, *The Dynamics of Asian Manufacturing*, 20–6.

Table 3.2: PPPs and intermediate input ratios in manufacturing, US and UK (1935)

	gross output PPP ($/£) [a]			*int. input PPP ($/£)* [b]			*value added PPP ($/£)* [c]			*II/GO (%)*	
branch/sector	*Laspeyres*	*Paasche*	*Fisher*	*Laspeyres*	*Paasche*	*Fisher*	*Laspeyres*	*Paasche*	*Fisher*	*US*	*UK*
Textiles	6.4	5.5	5.9	6.2	5.2	5.7 (5.5)	6.7	5.9	6.3	56	65
Leather	5.6	5.9	5.8	5.5	5.8	5.7	5.7	6.1	5.9	61	69
Clothing	5.3	5.0	5.1	6.1	5.4	5.7	4.3	4.5	4.4	57	55
Iron and steel	5.6	5.4	5.5	5.8	5.2	5.5 (5.4)	5.3	5.6	5.4	56	58
Engineering, ship. and vehicles	4.3	3.9	4.1	5.4	4.9	5.1	3.2	3.1	3.2	55	49
Non-ferrous metals	5.4	5.2	5.3	5.4	5.2	5.3	5.3	5.1	5.2	66	72
Food, drink and tobacco	5.9	5.2	5.5	5.7	5.7	5.7	6.2	4.2	5.1	70	62
Chemicals and allied products	5.1	3.2	4.1	5.3	3.8	4.5	4.9	2.6	3.5	63	54
Clay and building materials	5.4	5.5	5.5							38	36
Timber	2.2	2.2	2.2							45	53
Paper	4.0	3.7	3.9	4.1	3.6	3.8	3.9	3.9	3.9	41	39
Miscellaneous	6.2	4.5	5.3	5.3	5.7	5.5	7.1	3.8	5.2	49	52
Manufacturing	5.4	4.3	4.8	5.5	4.9	5.2	5.3	3.7	4.4	58	56

[a] The gross output *purchasing power parities* (PPP) are based on output *unit value ratios* (UVR) taken directly from the UK and US censuses; see appendix 3.A.

[b] The intermediate input PPPs are based on output UVRs of intermediate products weighted by data on the flow of these goods from input-output tables. The intermediate input PPPs between brackets are based on UVRs calculated from input-items taken directly from the UK and US censuses; see appendix 3.B.

[c] The value added PPPs are based on the input-output weighted intermediate input PPPs and the gross output PPPs. The Laspeyres and Paasche value added PPPs are derived using the methodology as specified in chapter 2.

Source: Board of Trade, *Final Report on the Fifth Census of Production and the Import Duties Act Inquiry (1935)* (London: H.M. Stationery Office, 1938–44); United States Department of Commerce: Bureau of the Census, *Biennial Census of Manufactures 1935* (Washington D.C.: United States Government Printing Office, 1938); T. Barna, "The Interdependence of the British Economy," *Journal of the Royal Statistical Society* 115 (1952): 29–81, table 3; W. Leontief, *The Structure of the American Economy, 1919–1939* (Oxford: Oxford University Press, 1951), table 24; for further details see H. de Jong and P. Woltjer, "A Comparison of Real Output and Productivity for British and American Manufacturing in 1935," *Groningen Growth and Development Centre Memorandum* 108 (2009): 1–34.

existing input-output tables. We used the 1935 table for the UK from Barna, and for the US the 1939 table from Leontief.[30] These input-output tables reveal that the great majority of the intermediate inputs for manufacturing industries originate from within the manufacturing sector itself. For example, in the large clothing and engineering trades nearly 90 percent of the inputs came from other manufacturing industries. It should be noted, however, that we have worked solely with ex-factory output prices and did not adjust for the costs of transport or trade margins, as the differences in these costs for both countries are unlikely to be so large as to have a substantial effect on the resulting intermediate input PPPs. We therefore implicitly assumed the trade and transport margins (relative to total costs) to be similar for both countries.

To construct the intermediate input PPPs we first estimated the US 1935 input-output table based on the available 1939 table. We adjusted the row and column totals for the 1939 input-output table to the 1935 gross output and intermediate inputs taken from the *Biennial Census of Manufactures* of 1935. The changes in the structure of the manufacturing sector could then be translated to the cells of the matrix itself to create a fit as close as possible to the original input-output table. Based on the structure of the British manufacturing sector, the Laspeyres output PPPs for products that are used further on in the production process (thus excluding the PPPs for final products) were then weighted by the flow of goods in the British input-output table to estimate industry and branch specific intermediate input PPPs. The same was done for the US; in this case the resulting PPPs were based on the US structure and Paasche PPPs. Only for the building materials and timber trades was it impossible to construct PPPs for intermediate inputs.

The resulting intermediate input PPPs are presented in table 3.2, in addition to the gross output PPPs and the resulting double deflated value added PPPs. As previously noted, for the textile and iron and steel branches the US census does provide specific value and quantity data on intermediate inputs, which made it possible to cross-check the reliability of the results we obtained from the input-output approach. The Fisher intermediate input PPPs between brackets are based on unit values derived directly from the manufacturing censuses, whereas all other intermediate input PPPs are derived from the input-output procedure. For the textile and iron and steel trades the intermediate input PPPs constructed by the alternative procedures differ within a margin of less than 4 percent, which we believe is reassuringly close and justifies our procedure of using the input-output tables to calculate input prices. Table 3.2 also shows that in some large branches PPPs for inputs are very different from those for

30. T. Barna, "The Interdependence of the British Economy," *Journal of the Royal Statistical Society* 115 (1952): 29–81, table 3; W. Leontief, *The Structure of the American Economy, 1919–1939* (Oxford: Oxford University Press, 1951), table 24.

output, notably in clothing, chemicals, and engineering.

3.4 Comparative labor productivity

Table 3.3 provides our new estimates of comparative labor productivity between the US and the UK. The first column presents the relative levels of gross output per worker, converted to a single currency by the single deflated Fisher PPPs listed in table 3.2. These output estimates are conceptually comparable to the direct comparisons of physical quantities of output as adopted by Rostas.[31] The second column presents the comparative levels of real value added per worker, converted by the double deflated Fisher PPPs of table 3.2. The latter represents our preferred new comparison of US/UK productivity for 1935.

Table 3.3 confirms the US lead for the manufacturing sector as a whole, as discussed in the introductory section. The double deflated estimate of 224 percent for US labor productivity is well over twice the level of the UK; the single deflated estimate is slightly lower at 212 percent. In both estimates, the UK performed comparatively well in textiles, leather, and food products, while the US had a solid lead in engineering, chemicals, and paper. Nonetheless, table 3.3 clearly shows that – as was the case for the Germany/UK comparison carried out by Fremdling et al. – the double deflation procedure does affect the comparative productivity estimates, particularly at the sectoral level.[32] For example, for the engineering, shipbuilding, and vehicles branch the single deflated productivity outcome underestimates US performance relative to the UK by a substantial margin. The differences between single and double deflated estimates stem from two sources. The main difference between the two approaches can be related to the fact that the double deflated benchmark estimates are a reconstruction of real value added, which provides a better approximation of economic performance, or the actual contribution of an industry to the value of the final product, than estimates of single deflated gross output do. This is of importance in particular when the ratio of intermediate inputs to gross output varies between countries as well as industries (what we call the input-share effect). Secondly, double deflation takes both the relative prices of industrial output and intermediate inputs into account (what we call the price effect). As shown by Fremdling et al., this procedure may give a more precise estimate of comparative performance because it adjusts for the price-distorting effects of policies that influence the foreign trade regime or the currency exchange rate. During the interwar period, protectionism and monetary policies led to substantial

31. See appendix 2.A in chapter 2 for a comparison between the ICOP approach, used in this chapter, and Rostas' quantity approach.
32. Fremdling, Jong, and Timmer, "British and German Manufacturing Productivity Compared," 353.

Table 3.3: Comparative labor productivity in manufacturing, US and UK (1935)

	labor productivity per worker (%, US/UK)	
branch/sector	*single deflated gross output*[a]	*double deflated value added*[b]
Textiles	124	144 (136)
Leather	127	157
Clothing	215	237
Iron and steel	173	186 (177)
Engineering, shipbuilding and vehicles	285	327
Non-ferrous metals	146	182
Food, drink and tobacco	177	152
Chemicals and allied products	287	263
Clay and building materials	201	*201*
Timber	293	*293*
Paper	285	278
Miscellaneous	211	231
Manufacturing	212	224

[a] The gross output per worker estimates were deflated by the Fisher gross output PPPs listed in table 3.2.

[b] The value added per worker estimates were deflated by the Fisher value added PPPs listed in table 3.2, with the exception of the 'clay and building materials' and 'timber' branches (in italics) which were deflated by the Fisher gross output PPPs. The figures in parentheses were deflated by 'standard' Fisher value added PPPs based on intermediate input UVRs taken directly from the UK and US censuses; see appendices 3.A and 3.B.

Source: Board of Trade, *Final Report on the Fifth Census of Production and the Import Duties Act Inquiry (1935)* (London: H.M. Stationery Office, 1938–44);
United States Department of Commerce: Bureau of the Census, *Biennial Census of Manufactures 1935* (Washington D.C.: United States Government Printing Office, 1938); for further details see H. de Jong and P. Woltjer, "A Comparison of Real Output and Productivity for British and American Manufacturing in 1935," *Groningen Growth and Development Centre Memorandum* 108 (2009): 1–34, appendix B.

Table 3.4: Comparative labor productivity in five major industries, US and UK (1935)

	share int. input in gross output (%)		*Fisher PPP ($/£)*			*labor productivity p. worker (%, US/UK)*	
industry	*US*	*UK*	*GO*	*II*	*VA*	*single defl. GO*	*double defl. VA*
Cotton products	61	71	5.7	5.4	6.2	113	142
Electrical engineering	43	46	4.1	5.4	3.4	245	318
Motor vehicles and bicycles	71	57	3.9	4.9	2.5	439	462
Chemical products	42	46	4.0	4.5	3.6	229	269
Rubber products	54	49	4.6	5.1	4.1	231	222

Source: see table 3.3.

differentials in relative input and output price movements, as shown in table 3.2. This supports the usefulness of the double deflation approach for the 1935 benchmark.[33]

To illustrate these effects, we have listed in table 3.4 the relevant statistics for five industries. For the cotton products, the share of intermediate inputs in gross output was considerably higher in the UK (71 percent) than in the US (61 percent). Using gross output as a proxy for the value added in this industry would thus potentially overestimate the comparative British labor productivity. Additionally, US relative prices for inputs (5.4 dollars per pound sterling) were lower than for output (5.7 $/£), resulting in a higher PPP for value added (6.2 $/£). Converting US output to pounds using the double deflated value added PPP, instead of the single deflated gross output PPP, obviously results in a downward adjustment of the productivity ratio. For the cotton products the effect of the adjustment for input shares is actually stronger than the adjustment for prices, and results, in this particular case, in an upward revision of the comparative productivity in favor of the US, from 113 to 142.

The effects of input-shares and prices can thus move in opposite directions. This is also the case in the motor vehicle and bicycle industry. US car manufacturers acquired a much larger percentage of gross output from intermediate inputs (71 percent) than their British counterparts (57 percent), which in this case points at a more developed pattern of specialization; an observation confirmed by Lewchuk.[34] In addition, the comparative price level of intermediate inputs between the US and the UK – relative to that of gross output – affects the actual levels of real value added per worker, when

33. Fremdling, Jong, and Timmer, "British and German Manufacturing Productivity Compared," 371.
34. W. Lewchuk, *American Technology and the British Vehicle Industry* (Cambridge: Cambridge University Press, 1987), 138–42. As a result of the different patterns of specialization for the motor vehicle and bicycle trade, the use of gross output as a measure of industrial productivity clearly overestimates the output of a US worker as compared to its British counterpart, since a considerable portion of US production consisted of intermediate inputs acquired from other industries.

the double deflation methodology is applied. Table 3.4 demonstrates that the PPP for gross output in the motor vehicle and bicycle industry (3.9 $/£) is considerably lower than the PPP for intermediate inputs (4.9 $/£), resulting in a PPP for value added (2.5 $/£) that is below the single deflated output PPP. The price effect turns out to be stronger than the input-share effect. Consequently, comparative US value added reveals a substantial lead over British car manufacturing (462), which is higher than the single deflated gross output per worker estimate (439).

The chemicals, dyestuffs, and drugs industry – which makes up the bulk of the chemicals branch – shows that both effects need not always be opposite. Here US producers required less inputs per unit of output, albeit only by a small margin, even though the relative price of these inputs was high compared to the relative price of outputs. Both the input-share effect and price effect raised the productivity estimate, resulting in an estimate much more in line with the other industries in the chemicals branch (see table 3.3).

3.5 Comparison with Rostas

In this section we compare our new estimates of labor productivity with the outcome of the physical output per worker estimates by Rostas. The problem we face here is that the theoretically more appropriate double deflated productivity figures are not directly comparable with Rostas's outcomes. Therefore we rely on our real gross output per worker estimates (and not on our preferred real value added estimates), as they are conceptually on the same footing as the comparative productivity figures provided by Rostas. Whereas we were able to draw on nearly complete sets for all manufacturing industries in the censuses, Rostas's choice was dictated by the availability of about 30 pairs of industries – as listed in table 3.5 – covering less than half of total output in manufacturing. Important industries such as shipbuilding, non-ferrous metals, timber, heavy chemicals, petroleum refining, tailoring, printing, and leather were omitted in the study by Rostas. In these cases he was not able to collect systematic data on employment and output for both countries, which he noted himself was a major shortcoming of his work.[35]

Table 3.5 compares the outcomes of both studies and reveals substantial differences on the level of individual industries.[36] These differences are caused by two main factors. Firstly, the classification of industries as listed by Rostas is not in line with the classification used in the US or British census, and for that matter, with our own

35. Rostas, *Comparative Productivity in British and American Industry*, 29.

36. Rostas's results listed in table 3.5 are based on a 1935/1937 comparison summarized by Broadberry and Crafts, "Britain's Productivity Gap in the 1930s."

classification. As the quantity method utilized by Rostas required him to match employment with a specific quantifiable measure of output – either in the form of a single product or a group of broadly comparable items – his choice of industries was limited to those with a fairly homogenous product structure and prevented him from aggregating over industries to match the US and British industry classifications. Hence the industries listed in Rostas's study are at the lowest possible level of aggregation, and in some cases represent only parts of an industry as defined in both censuses. Secondly, even though Rostas restricted his study to those industries with a very homogenous product structure, in several cases he was forced to combine the physical output of several clearly distinct products to get a measure of comparative productivity. Our study actually makes it possible to compare separate products within a single industry between the US and the UK one by one. This method allowed us to cover a much broader sample of products and to take quality differences into account. For the motor vehicle and bicycle trade, for example, we were able to compare the prices of 15 different products in the US and the UK, ranging from car-axles to 15-ton trucks, thus increasing both the coverage and accuracy of our conversion factors.

The only industry covered by Rostas in the clothing trades was the boots and shoes trade, about 25 percent of the total size of the branch. Rostas's relatively low estimate for this industry can most likely be explained by the non-homogeneity of the final products for this category. He had to rely on a rather rudimentary conversion factor and in addition had to integrate the sizable US 'boot and shoe, cut stock and findings' trades into the industry. As our present estimate reveals, the boots and shoes trade is not representative of the clothing branch as a whole, which is primarily driven by the substantial US productivity lead in the large tailoring, dressmaking, and millinery trades.[37]

Our present study confirms the large productivity lead of the US in the machinery and electrical engineering industries. However, the extent of the US lead in the machinery industry, in terms of real gross output per worker, is overstated substantially by the method applied by Rostas. Due to the complex nature of machinery production, Rostas chose to deflate the total value of output using the official exchange rate. This is likely to have biased the comparative productivity estimate, as the cross-country differences in the comparative price ratios between the goods produced in this industry were not taken into account. For electrical engineering Rostas was able to match two product groups, radios and electric lamps, which comprised together only 13 percent of the industry. However, he was unable to aggregate these product groups into the broader group of electrical engineering that was delimited in both census reports. In addition,

37. See table 3.3; in addition, see Jong and Woltjer, "A Comparison of Real Output and Productivity," appendix B, for an overview of all industries.

Table 3.5: Gross output per worker in manufacturing, US and UK (1935)

	output per worker (% US/UK)	
Industry[a]	*This study (real gross output per worker)*	*Rostas (physical output per worker*
Bricks	155	132
Glass containers	206	264
Cement	93	99
Coke and by-products	205	236
Soap	288	285
Matches	593	336
Seed crushing	94	105
Blast furnaces	311	362
Steel works	119	197
Iron foundries	179	154
Machinery	218	268
Radios	245	347
Electric lamps	245	543
Motor cars	439	294
Cotton spinning and weaving	113	150
Woollen and worsted	100	131
Rayon	117	185
Hosiery	184	156
Boots and shoes	170	141
Grain milling	136	173
Biscuits milling	268	345
Beet sugar	106	102
Margarine	140	152
Fish curing	98	50
Manufactured ice	163	219
Brewing	201	201
Tobacco	117	160
Paper	258	247
Rubber tyres and tubes	223	285
Linoleum and oilcloth	162	170

[a] The product group 'tin cans' has been omitted from this list, as it was not possible to distinguish it as a separate industry in the British census. For reasons of comparability we kept the arrangement of the industries and the names above in line with the list provided in S. Broadberry and N. Crafts, "Britain's Productivity Gap in the 1930s: Some Neglected Factors," *Journal of Economic History* 52 (1992): 543. Note that the figure of comparative productivity we provide for the industry 'motor cars' is identical to 'motor vehicles and bicycles' listed in table 3.4; the figures for 'radios' and 'electric lamps' are based on 'electrical engineering', 'cotton spinning and weaving' is based on 'cotton products', and 'rubber tyres and tubes' is identical to the 'rubber products' category.

Source: Real gross output per worker, see table 3.3. Physical output per worker: L. Rostas, *Comparative Productivity in British and American Industry* (Cambridge: Cambridge University Press, 1948); S. Broadberry and N. Crafts, "Britain's Productivity Gap in the 1930s: Some Neglected Factors," *Journal of Economic History* 52 (1992): 543.

the comparative productivity for the small sample of products, on which Rostas based his estimate for the electrical engineering industry, is substantially above our own estimate for this industry, and serious doubts can be cast on the representativeness of these specific products for the productivity estimate for the group as a whole. Furthermore, because Rostas used quantity indicators of output for his comparison, his estimates reflect gross output per worker instead of value added per worker.[38] Thus he could not take account of the effects of relative differences in the shares and prices of intermediate inputs between the two countries. Table 3.3 has shown that such an adjustment is essential in the case of the engineering, shipbuilding, and vehicles branch. Rostas noted the latter point as a major limitation of his quantity approach but was unable to address it at the time.[39]

The absence of the sector of chemicals, dyestuffs, and drugs among the estimates of table 3.5 reflects another weakness in the quantity approach. Because of its complex structure – the sector encompassed well over 200 appreciably different products – it was simply not possible for Rostas to find a common conversion factor, or to assign labor to the various products. Consequently he decided to omit this industry, even though it was by far the largest industry of the branch. Our new estimate of the chemical and allied trades – which includes the chemicals, dyestuffs, and drugs trades and is based on 83 important products in this category – thus presents a major improvement over the original estimation by Rostas.

Overall, the discrepancies between our new estimates and the quantity method fundamentally challenge studies relying on Rostas's disaggregated figures. His study is less representative for the total manufacturing sector and the methodology applied is unable to account for the effects of relative prices and volumes of intermediate inputs used in the British and US production process. Studies using Rostas's estimates in analyzing comparative productivity figures for British and American manufacturing industries are undoubtedly biased. Regardless of the shortcomings of his approach, however, the comparative productivity estimate by Rostas for the manufacturing sector as a whole is remarkably close to the present estimate. On the total industry level Rostas arrived at a figure of US/British comparative productivity of 212–215 percent, whereas we have estimated a level of 212 percent (single deflated gross output, see table 3.3).[40] This may be seen as good news for those studies that continue to use quantity comparisons on the practical grounds that there are insufficiently reliable prices available. However, we firmly believe that this result for the aggregate manufacturing sector is more likely to mirror the hard work and impeccable judgment of Rostas,

38. See appendix 2.A in chapter 2 for a comparison between the ICOP approach, used in this chapter, and Rostas' quantity approach.

39. Rostas, *Comparative Productivity in British and American Industry*, 3.

40. ibid., 33.

rather than the validity of using physical quantities as the measure in productivity comparisons.

3.6 Hours of work

Most historical cross-country productivity comparisons apply the concept of output per worker or real value added per worker. However, we think that in the present context real value added per person-hour is the preferred indicator of labor productivity, as it is best suited to the concepts of economic efficiency and technological capabilities. For the present study this distinction is of particular importance since the decline in weekly actual hours worked in the US was more pronounced than in Britain during the 1930s. The practice of work sharing was widespread in the US depression economy. If we do not adjust for this we would underestimate US comparative productivity. Clark estimated the average working week in Great Britain in 1935 at 47.8 hours, compared to only 37.2 hours in the US.[41] Likewise, Rostas assumed the average length of the UK and US working week to be 47.8 and 36.6 hours, respectively. However, he did not analyze the effects of this gap in working hours on the actual level of Anglo-American comparative productivity.[42] The lower levels of US working hours are confirmed in the study of actual hours of work per week by Jones.[43] For the UK, systematic evidence is more difficult to find.[44] Some occasionally published government statistics give the percentage of short-time workers and the quantity of short-time work.[45] However, we made estimates of actual hours worked on the basis of information given by Hart, and by Huberman and Minns.[46]

The *Yearbook of Labour Statistics* of 1939 contains detailed statistics on average hours of work per worker per week for several industries and industry groups within manufacturing for both the UK and the US.[47] We weighed these outcomes by em-

41. Clark, *The Conditions of Economic Progress*, 68.

42. Rostas, *Comparative Productivity in British and American Industry*, 25, 27, 29, 43–4, 48–9. He did not adjust for hours worked for two reasons. Firstly, he was more interested in measuring manpower requirements than in measuring the effect of comparative productivity on production costs. Secondly, he (mistakenly) held the belief that the relatively short hours in the US were part and parcel of the mass-production methods utilized there and for that reason per worker comparisons would be more realistic.

43. Jones, "New Estimates of Hours of Work per Week," 375; see also International Labour Office, *Year Book of Labour Statistics 1939* (Geneva, 1939), and Carter et al., *Historical Statistics of the United States*.

44. N. Whiteside and J. Gillespie, "Deconstructing Unemployment: Developments in Britain in the Interwar Years," *Economic History Review* 44 (1991): 674, 677.

45. M. Thomas, "Labour Market Structure and the Nature of Unemployment in Interwar Britain," chap. 5 in *Interwar Unemployment in International Perspective*, ed. B. Eichengreen and T. Hatton (Dordrecht: Kluwer Academic Publishers, 1988), 136.

46. R. Hart, "Hours and Wages in the Depression: British Engineering 1926–1938," *Explorations in Economic History* 38 (2001): 7; Huberman and Minns, "Days and Hours of Work in Old and New Worlds," 546–8.

47. International Labour Office, *Year Book of Labour Statistics 1939*.

Table 3.6: Weekly and annual average hours worked in manufacturing, US and UK (1935)

	United States		*United Kingdom*	
branch/sector	*weekly hours*	*annual hours*	*weekly hours*	*annual hours*
Textiles	35.8	1,774	47.7	2,250
Leather	38.6	1,915	48.8	2,302
Clothing	32.2	1,597	45.4	2,142
Iron and steel	36.6	1,813	48.2	2,274
Engineering, shipbuilding and vehicles	36.5	1,809	48.2	2,274
Non-ferrous metals	37.1	1,838	48.2	2,274
Food, drink and tobacco	39.5	1,962	48.5	2,288
Chemicals and allied products	38.1	1,892	48.0	2,264
Clay and building materials	36.5	1,812	48.0	2,264
Timber	39.5	1,958	48.3	2,278
Paper	38.2	1,896	48.6	2,292
Miscellaneous	33.9	1,682	48.2	2,274
Manufacturing	36.6	1,817	47.8	2,255

Source: International Labour Office, *Year Book of Labour Statistics 1939* (Geneva, 1939); Ministry of Labour, *Twenty-Second Abstract of Labour Statistics of the United Kingdom (1922–1936)* (London: H.M. Stationery Office, 1937), 96–7, 104–7; M. Huberman and C. Minns, "The Times They are not Changin': Days and Hours of Work in Old and New Worlds, 1870–2000," *Explorations in Economic History* 44 (2007): 546–8.

ployment to obtain the familiar branch classification that adheres to the British census. Data from Huberman and Minns on the number of vacations and holidays in the UK and US in 1938 made it possible to construct the total number of annual hours worked.[48] The data on weekly and annual average hours worked in 1935 are presented in table 3.6.

The study by Jones illustrates that the decline in weekly hours in the US was 'deep, prolonged, and widespread' during the 1930s.[49] Bernanke explained the drop in the US work week and the introduction of work sharing as an efficient way for firms to react to falling demand: firms cut production by running certain operations only part-time; at the same time the work force was left intact by spread-work schedules.[50]

Table 3.7 presents labor productivity statistics on a person-hour basis. The branch specific employment data have been multiplied by the data on annual hours worked from table 3.6. This results in an average level of US labor productivity per hour for to-

48. Huberman and Minns, "Days and Hours of Work in Old and New Worlds," 546.
49. R. Margo, "Employment and Unemployment in the 1930s," *Journal of Economic Perspectives* 7 (1993): 48.
50. B. Bernanke, "Employment, Hours, and Earnings in the Depression: An Analysis of Eight Manufacturing Industries," *American Economic Review* 76 (1986): 86.

Table 3.7: Real value added per worker and per hour in manufacturing, US and UK (1935)

branch/sector	*value added per worker (%, US/UK)*[a]	*value added per hour (%, US/UK)*[a]
Textiles	144	182
Leather	157	190
Clothing	237	318
Iron and steel	186	235
Engineering, shipbuilding and vehicles	327	410
Non-ferrous metals	182	226
Food, drink and tobacco	152	177
Chemicals and allied products	263	316
Clay and building materials	*201*	253
Timber	*293*	345
Paper	278	338
Miscellaneous	231	313
Manufacturing	224	279

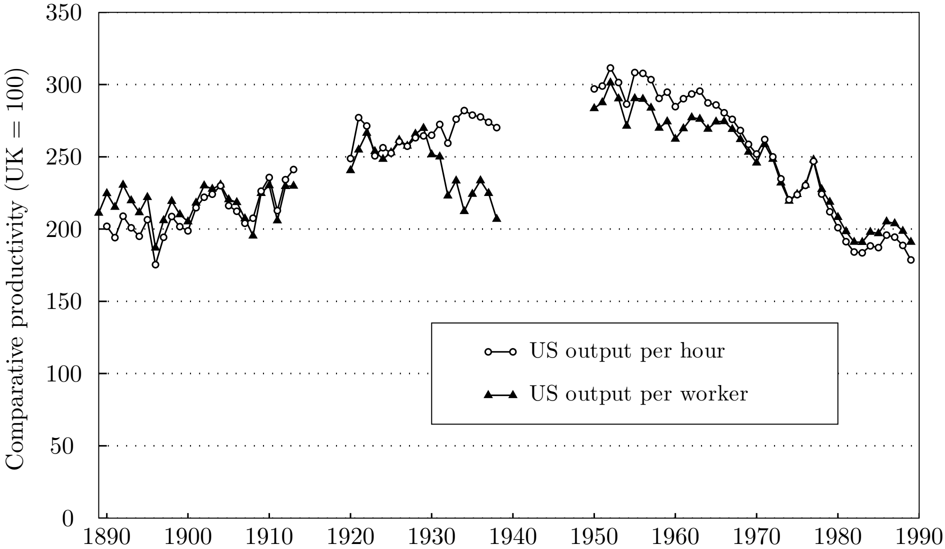
[a] The value added per worker/person-hour estimates were deflated by the Fisher value added PPPs listed in table 3.2, with the exception of the 'clay and building materials' and 'timber' branches (in italics) which were deflated by Fisher gross output PPPs.
Source: see tables 3.2, 3.3 and 3.6.

tal manufacturing of 279 percent of the British level, which is 55 percentage points (or 25 percent) higher than the productivity per worker estimate. On the level of branches the rise in measured labor productivity ranged from 16 percent (food, drink, and tobacco) to 34 percent (clothing). In 1935 hourly productivity in US engineering was more than four times as high as in the UK.

These new results seem difficult to reconcile with the productivity per worker outcome of Rostas's benchmark for manufacturing. The same holds for studies based on this estimate, such as Broadberry's backward and forward time series projections of US/UK productivity. By making these extrapolations Broadberry implicitly assumed that working hours have moved correspondingly in the UK and the US. The data presented here show that this was not the case in the interwar period. The line with the solid triangular markers in figure 3.1 illustrates the comparative labor productivity for the American and British manufacturing sectors over the period 1890–1990 on a per worker basis, which is similar to the overview of comparative manufacturing productivity in Broadberry's work.[51] With our new information on differential working hours we projected a time series backward and forward from the 1935 benchmark level of 279, on an hourly basis. We used the same time series on output and employ-

51. Broadberry, *The Productivity Race*, 2.

Figure 3.1: Comparative labor productivity in manufacturing, US and UK (UK=100, 1890–1990)



Source: Benchmark 1935: based on double deflated estimates listed in table 3.3 (per worker) and table 3.7 (per hour). Time series output and number of workers: S. Broadberry, *The Productivity Race: British Manufacturing in International Perspective, 1850–1990* (Cambridge: Cambridge University Press, 1997), 42–5. UK annual average hours worked: M. Huberman and C. Minns, "The Times They are not Changin': Days and Hours of Work in Old and New Worlds, 1870–2000," *Explorations in Economic History* 44 (2007): 546–8; R. Hart, "Hours and Wages in the Depression: British Engineering 1926–1938," *Explorations in Economic History* 38 (2001): 7; C. Clark, *The Conditions of Economic Progress*, 2nd (London: MacMillan, 1951), 68; International Labour Office, *The ILO Year-book* (Geneva, 1931); International Labour Office, *Year Book of Labour Statistics 1939* (Geneva, 1939); International Labour Office, *Year Book of Labour Statistics 1962* (Geneva, 1962);
The Conference Board, "Total Economy Database," 2008. US annual average hours worked: E. Jones, "New Estimates of Hours of Work per Week and Hourly Earnings, 1900–1957," *Review of Economics and Statistics* 45 (1963): 375; M. Huberman and C. Minns, "The Times They are not Changin': Days and Hours of Work in Old and New Worlds, 1870–2000," *Explorations in Economic History* 44 (2007): 546–8; The Conference Board, "Total Economy Database," 2008.

ment (number of workers) as Broadberry, and adjusted it for the movements of average weekly hours per worker in both countries.[52] This new graph reveals that the level of comparative value added per person-hour was slightly below the level of value added per worker in 1890. At the end of the nineteenth century the US had a labor productivity lead of about twice the level of the UK. From the final decades of the nineteenth century the comparative US level increased, per worker as well as per hour. The two series move in unison from 1900 into the 1920s. After 1929, however, the value added per person-hour series does not show the downward movement in comparative labor productivity that is so typical of the comparative value added per worker series. There is no longer any indication of a 'temporary cyclical narrowing' of the gap before the Second World War, but an upward trend from the end of the nineteenth century into the postwar period. After the war there is still a gap between the two series which persists well into the 1960s.

We conclude from this new series that there is a clear trend in the widening of the US/UK productivity gap when we measure productivity in terms of actual hours worked. This long-term process appears not to have been affected greatly by the exogenous shocks of the world wars. During this period US manufacturing increased its productivity lead (measured in hours) over the UK from less than 200 percent in 1890 to over 300 percent in the 1950s. This implies that the stylized fact of a 2:1 productivity ratio between the US and the UK can only be substantiated using the concept of labor productivity per worker. However, in transatlantic comparisons in particular it is important to employ the proper measure of productivity based on actual hours worked. Productivity measured in hours thus provides a fundamentally different picture of the long-term comparative industrial performance of the US, in line with the results reported by Field.[53]

3.7 Conclusion

This chapter presents an industry-of-origin study of interwar US and UK manufacturing productivity performance that has a different approach from the estimates made by Rostas. We have used the census reports of 1935 to calculate Anglo-American comparative labor productivity levels for all manufacturing industries. The input-output structure of both economies has been applied to calculate prices of intermediate inputs. Therefore real value added could be estimated by performing a double deflation procedure. Average annual hours worked on both sides of the Atlantic diverged

52. Kendrick, *Productivity trends in the United States*, 465–75; Feinstein, *Statistical Tables of National Income, Expenditure and Output of the UK*, T111–3, T130.
53. Field, "The Most Technologically Progressive Decade of the Century," 1399.

greatly in the interwar period. When we adjust employment figures for actual hours worked, the US comparative productivity level rises to almost 280 percent of that of British manufacturing in 1935. Hours adjustment also produces major changes in the long-term trend of comparative productivity in manufacturing between the two countries. US/UK hourly productivity in manufacturing steadily moved from a level of 200 around 1900 to a level of 300 in the period directly following the Second World.

Broadberry and Crafts have tried to explain the fundamental long-run forces underlying the interwar US/UK manufacturing productivity gap. Regression estimates include effects from higher concentration ratios and lower quality of human capital in British industries.[54] Restrictive practices in interwar Britain may also have hampered competition and the necessary economic adjustment to new technologies. There was less rapid technical change compared with the US, maintaining a low effort equilibrium that was carried over into the postwar period.[55] Hannah has stressed the detrimental influence of protectionism and of the wars on European performance: 'it is surely not necessary to look much further for the sources of the American miracle than the geopolitical maladies that afflicted her major potential competitors'.[56]

Focusing on 'European failure' is only part of the story, however. We believe that it is also necessary to stress the sources of US success as well. US comparative performance resulted from strong domestic modernization in the key sectors of the second industrial revolution. The interwar years witnessed the implementation and exploitation of new technologies and practices which were to form the basis of much of the labor and total-factor productivity of the postwar period. The US advance reflected also the movement along scientific and technological trajectories relatively unaffected by the macroeconomic downturn of the 1930s. Nelson and Wright have mentioned the rise of electrical and chemical engineering in particular. The shift from coal to petroleum as the basic feedstock for chemical plants is seen as a "remarkable blend of mass production, advanced science, and American resources".[57] Superimposed on the depressed purchasing power of consumers were long-term developments such as advances in consumer-product and service oriented industries, characterized by technical change and product innovation. Bernstein has pointed at chemicals, petroleum, tobacco, food products, machinery, rubber, plastic products, transportation equipment, paper, and fabricated metal as being among the most dynamic and successful indus-

54. Broadberry, *The Productivity Race*; Broadberry and Crafts, "Britain's Productivity Gap in the 1930s," 544–5; see chapter 5 for a discussion.

55. ibid., 554; G. Magee, "Manufacturing and Technological Change," chap. 4 in Floud and Johnson, *The Cambridge Economic History of Modern Britain*, 2:95; see chapter 4 for a discussion.

56. Hannah, "Logistics, Market Size, and Giant Plants in the Early Twentieth Century," 210.

57. R. Nelson and G. Wright, "The Rise and Fall of American Technological Leadership: The Postwar Era in Historical Perspective," *Journal of Economic Literature* 30 (1992): 1946; see also D. Mowery and N. Rosenberg, "Twentieth-century Technological Change," chap. 14 in *The Cambridge Economic History of the United States*, ed. S. Engerman and R. Gallman, vol. 3 (Cambridge: Cambridge University Press, 2000), 803–925.

tries.[58] Field has stressed the role of disembodied technical change and the advance of knowledge in the outward shift of the US production possibility frontier. There is much evidence of important process and product breakthroughs as drivers of productivity advance, such as floor space savings, automatic process control, larger units of installations, increased thermal efficiency, improved materials, and the expansion of R&D laboratories.[59] Bresnahan and Raff showed that a major role was also played by the change in the composition of firms within and between industries.[60] The US motor vehicle industry provides an archetypical example of growth of efficiency within an industry as a direct cause of the removal of the low productivity tail in the spread of plants – due to falling demand during the depression that affected the weakest firms foremost – resulting in a one-off change in the composition of the entire industry. Only the large motor vehicle production plants survived in the depression years and new entrants had higher productivity.

Our study reveals that many of the industries just mentioned show very high levels of hourly labor productivity, such as the motor vehicle and bicycle trade (545); blast furnaces (405); electrical engineering (389); chemicals, dyestuffs, and drugs (315); paper (338); and rubber (300).[61] It confirms that fast comparative productivity advances were visible in many branches in US manufacturing, but particularly in engineering, and in process industries like chemicals and paper. Disentangling each industry's individual contribution to overall sectoral productivity growth is an important avenue for future research into the explanation of high interwar comparative US productivity levels. Shift-share analysis of the growth of manufacturing branches in the period 1900–1957 reveals that US comparative productivity levels as well as productivity growth were particularly high in chemicals and engineering.[62] In other words, US manufacturing managed to expand much faster those sectors in which it already had comparative and competitive leadership.

We conclude that the US overtaking of the UK in terms of aggregate labor productivity was not just caused by shifts from labor out of agriculture or the result of comparative productivity increases in the service sector.[63] It was as much the effect of productivity growth within manufacturing itself. Thus manufacturing can still be viewed as a major force in driving convergence or divergence of labor productivity. Finally, our comparative data reveal that it was not the Second World War that was the

58. Bernstein, "The Response of American Manufacturing Industries to the Great Depression," 228, 237–41.

59. Field, "Technological Change and US Productivity Growth," 214–5.

60. T. Bresnahan and D. Raff, "Intra-Industry Heterogeneity and the Great Depression: The American Motor Vehicles Industry, 1929–1935," *Journal of Economic History* 51 (1991): 327–40.

61. Jong and Woltjer, "A Comparison of Real Output and Productivity," appendices A and B.

62. ibid., 32.

63. Broadberry, "How Did the United States and Germany Overtake Britain?," 400.

decisive factor in rapid US comparative productivity growth in manufacturing.[64] During the 1930s the transatlantic productivity gap continued to widen, which is manifest in the 1935 census reports of the UK and the US.

64. See also Field, "The Impact of the Second World War on US Productivity Growth," 676, 688, 690.

3.A Output unit value ratios

Table 3.8: Output UVRs, US and UK (1935)

description	quantity unit	United States quantity (x,000)	United States value ($,000)	United Kingdom quantity (x,000)	United Kingdom value (£,000)	uvr ($/£)
Wheat: meal, flour, etc.	Tons (long)	12,979	792,164	5,670	46,381	7.5
Maize: flour and meal	Tons (long)	671	32,485	974	4,934	9.6
Rice: cleaned	Tons (long)	514	41,581	40	556	5.9
Animal feeds	Tons (long)	5,555	222,698	736	5,384	5.5
Bread	Pounds	9,307,579	706,898	7,028,000	44,700	11.9
Biscuits	Pounds	1,323,045	179,602	539,056	16,654	4.4
Cocoa: powdered	Pounds	9,003	1,520	34,496	1,778	3.3
Chocolate: bars and blocks	Pounds	272,406	43,938	206,528	8,192	4.1
Confectionery: chocolat	Pounds	718,157	120,620	228,032	10,030	3.8
Confectionery: hard goods	Pounds	251,282	28,109	182,448	4,666	4.4
Confectionery: soft goods	Pounds	118,607	15,018	192,976	5,335	4.6
Confectionery: toffees	Pounds	151,432	14,991	135,184	3,459	3.9
Peas: canned and bottled	Pounds	758,944	50,820	67,312	1,138	4.0
Vegetables: canned and bottled	Pounds	2,623,810	134,550	68,544	1,014	3.5
Hams: cooked	Pounds	108,317	35,581	41,216	2,196	6.2
Pork: salted, pickled and smoked	Pounds	1,968,107	393,507	232,624	9,810	4.7
Lard	Pounds	915,646	128,815	124,544	3,474	5.0
Sausages and meat puddings	Pounds	1,333,906	228,464	219,632	7,373	5.1
Sausage casings	Pounds	127,876	32,245	14,112	870	4.1
Butter	Pounds	1,653,142	464,579	192,954	8,508	6.4
Cheese: cheddar	Pounds	491,595	70,494	17,797	341	7.5
Cheese: cream	Pounds	41,805	8,136	605	34	3.5
Condensed milk: whole, sweetened	Pounds	136,481	9,779	154,493	2,618	4.2
Condensed milk: skimmed, sweetened	Pounds	120,462	5,086	114,150	1,075	4.5
Condensed milk: not sweetened	Pounds	2,186,928	118,750	63,538	1,080	3.2
Powdered milk: whole	Pounds	22,784	3,232	19,230	776	3.5
Powdered milk: skimmed	Pounds	296,175	15,824	20,485	195	5.6
Margarine	Pounds	388,894	47,257	395,158	6,186	7.8
Casein	Pounds	48,987	4,273	1,322	24	4.8
Sugar: unrefined	Pounds	521,680	15,953	602,112	2,703	6.8
Sugar: refined	Pounds	10,956,872	468,607	4,859,904	33,652	6.2
Beet pulp: dry	Pounds	263,454	1,525	85,008	148	3.3
Beet pulp: molassed	Pounds	265,906	1,732	534,352	938	3.7
Beet pulp: wet	Tons (long)	1,144	928	103	24	3.5
Cured fish: herring	Pounds	18,755	1,614	312,480	2,143	12.5
Cured fish: cod	Pounds	12,584	1,595	58,464	822	9.0
Manufactured ice	Tons (long)	29,161	126,621	1,173	970	5.3
Beer	Gallons (UK)	1,007,931	336,490	787,536	54,898	4.8
Malt	Pounds	2,005,367	70,926	619,696	4,470	4.9
Fruit juices, syrups and cordials	Gallons (UK)	40,313	66,771	1,736	533	5.4
Cigarettes	Pounds	321,777	294,221	153,187	38,461	3.6
Cotton yarn: single	Pounds	390,037	133,569	1,159,628	53,287	7.5
Cotton yarn: doubled	Pounds	50,733	13,948	181,203	16,658	3.0
Waste: cotton (unmanufactured)	Pounds	338,673	21,027	241,429	2,634	5.7
Woven products: cotton	Pounds	1,570,868	561,232	761,488	52,679	5.2
Pile fabrics: cotton	Pounds	37,242	21,981	9,968	959	6.1
Handkerchiefs: cotton	Dozen	31,798	18,122	11,335	1,269	5.1
Bed coverings: cotton	Pounds	12,033	5,503	19,264	1,410	6.2

continued on next page...

Table 3.8 - continued from previous page

desc	*unit*	*us_q*	*us_v*	*uk_q*	*uk_v*	*uvr*
Towels: cotton	Pounds	72,112	30,944	30,352	2,036	6.4
Tops: wool	Pounds	7,607	6,192	216,142	19,771	8.9
Noils: wool	Pounds	11,874	5,615	30,973	1,802	8.1
Yarns: wool, mohair, etc.	Pounds	97,947	101,595	281,090	35,068	8.3
Woollen and worsted tissues	Pounds	57,234	60,094	232,990	42,318	5.8
Carpets and rugs: velvet and tapestry, wool	Sq. Yd.	16,235	30,269	6,741	1,215	10.3
Carpets and rugs: Wilton, wool	Sq. Yd.	5,285	15,884	4,663	1,927	7.3
Carpets and rugs: Axminster, wool	Sq. Yd.	24,201	44,239	21,618	6,793	5.8
Blankets: wool	Pounds	16,906	23,608	24,889	2,218	15.7
Hosiery: cotton	Dozen pairs	27,509	33,575	4,168	1,332	3.8
Hosiery: wool	Dozen pairs	881	2,516	12,495	6,167	5.8
Hosiery: silk	Dozen pairs	40,877	201,399	4,838	4,542	5.2
Hosiery: artificial silk	Dozen pairs	18,404	25,184	9,675	4,025	3.3
Underwear: cotton	Dozen	20,044	62,958	6,852	4,322	5.0
Underwear: wool	Dozen	1,853	13,888	2,382	3,726	4.8
Underwear: silk	Dozen	7,137	59,126	49	165	2.5
Underwear: artificial silk	Dozen	13,128	45,722	2,343	2,530	3.2
Fancy hosiery	Dozen	11,533	120,807	5,064	9,721	5.5
Neckties, knitted	Dozen	425	1,019	291	166	4.2
Knitted fabric: cotton	Pounds	10,796	3,856	2,156	228	3.4
Knitted fabric: wool	Pounds	8,369	10,650	2,390	529	5.7
Knitted fabric: artificial silk	Pounds	28,577	21,383	16,083	4,391	2.7
Cotton net: finished	Square yards	7,811	3,666	15,207	365	19.6
Twine: hard hemp, manila	Pounds	120	19	1,702	25	10.7
Twine: hard hemp, sisal	Pounds	36,841	3,017	32,894	435	6.2
Cordage: hard hemp, manila	Pounds	75,390	9,050	72,587	992	8.8
Cordage: hard hemp, sisal	Pounds	6,859	547	13,294	180	5.9
Twine, soft hemp	Pounds	807	228	16,296	613	7.5
Cordage, soft hemp	Pounds	146	49	1,971	116	5.7
Twine: jute	Pounds	22,215	2,617	7,963	149	6.3
Twine: flax	Pounds	1,556	779	2,397	167	7.2
Cordage: cotton	Pounds	22,750	5,908	5,522	307	4.7
Waste: wool (manufactured)	Pounds	20,494	2,725	120,736	2,586	6.2
Waste: cotton (manufactured)	Pounds	142,164	9,248	98,112	968	6.6
Linoleum: inlaid	Square yards	17,675	13,193	19,841	2,181	6.8
Linoleum: printed	Square yards	2,197	1,000	42,667	2,744	7.1
Cork carpet	Square yards	215	189	659	96	6.0
Floor coverings: felt base	Square yards	66,631	14,461	42,270	1,027	8.9
Floor coverings: oilcloth	Square yards	8,230	1,593	6,879	270	4.9
Leather cloth and other oilcloth	Square yards	57,306	17,130	49,155	2,827	5.2
Overcoats: men's and boys'	Number	6,249	78,792	2,573	2,475	13.1
Rubber/oil proofed garments: male	Number	5,730	12,801	3,176	1,320	5.4
Rainproof garments: male	Number	4,644	13,884	2,683	2,742	2.9
Rubber proofed garments: male	Number	1,380	3,207	3,081	962	7.4
Oil proofed garments: female	Number	49	95	184	60	5.9
Aprons and overalls: male	Number	78,903	60,188	10,645	2,039	4.0
Aprons: female	Number	31,355	8,698	41,456	3,559	3.2
Undergarments: male	Dozen	18,786	147,568	3,222	6,427	3.9
Collars and cuffs	Dozen	1,212	2,652	3,072	841	8.0
Corsets and allied garments	Number	76,975	64,232	24,972	4,197	5.0
Millinery: trimmed hats	Dozen	8,743	85,189	871	2,367	3.6
Neckties and scarves	Dozen	18,200	58,418	4,097	2,583	5.1
Suspenders and allied garments	Dozen	7,682	11,944	3,013	908	5.2
Handkerchiefs	Dozen	31,798	18,122	644	177	2.1

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Table 3.8 - continued from previous page

desc	unit	us_q	us_v	uk_q	uk_v	uvr
Boots and shoes: leather, men's	Pairs	96,650	210,175	30,912	12,951	5.2
Boots and shoes: leather, women's	Pairs	146,286	281,067	46,728	16,526	5.4
Boots and shoes: leather, boys' and youths'	Pairs	18,500	27,922	7,908	1,712	7.0
Boots and shoes: leather, girls'	Pairs	43,521	47,429	13,500	2,386	6.2
Boots and shoes: leather, infants'	Pairs	19,076	13,325	9,060	828	7.6
Slippers	Pairs	39,020	25,290	18,564	2,219	5.4
Hardwood lumber: mahogany	Cub. Meters	27	1,423	12	158	4.0
Hardwood lumber: walnut	Cub. Meters	55	1,755	1	14	2.9
Hardwood lumber: oak	Cub. Meters	2,819	32,433	143	1,054	1.6
Hardwood lumber: ash	Cub. Meters	211	2,688	24	213	1.4
Hardwood lumber: beech	Cub. Meters	223	2,230	25	139	1.8
Hardwood lumber: elm	Cub. Meters	157	1,670	42	216	2.1
Hardwood lumber: other	Cub. Meters	4,221	46,230	51	344	1.6
Softwood lumber: redwood and Douglas fir	Cub. Meters	12,038	86,006	524	1,851	2.0
Softwood lumber: other	Cub. Meters	26,303	224,049	547	1,782	2.6
Dressed lumber	Cub. Meters	23,618	225,767	1,373	6,107	2.1
Coopering: wet, breweries and distilleries	Number	3,885	17,503	170	291	2.6
Coopering: wet, other	Number	4,216	7,552	208	134	2.8
Coopering: dry	Number	21,471	10,021	985	134	3.4
Printing paper: newsprint	Tons (long)	846	33,354	857	8,051	4.2
Printing paper: other	Tons (long)	1,336	110,268	392	7,714	4.2
Writing paper	Tons (long)	453	70,620	146	4,781	4.8
Packing paper: kraft	Tons (long)	880	66,180	113	1,805	4.7
Packing paper: sulphite	Tons (long)	297	26,337	16	291	4.8
Packing paper: manila	Tons (long)	69	6,743	6	155	3.9
Greaseproof paper	Tons (long)	11	2,256	14	315	9.2
Paper: oiled, waxed and waterproof	Tons (long)	33	8,011	25	1,131	5.4
Cigarette paper	Tons (long)	27	5,739	4	451	1.8
Blotting paper	Tons (long)	10	1,965	6	389	3.0
Vegetable parchment	Tons (long)	13	1,813	14	443	4.5
Building paper	Tons (long)	393	19,450	28	340	4.1
Strawboard, leatherboard and imitation leatherboard	Tons (long)	582	24,700	71	662	4.5
Cardboard and millboard	Tons (long)	1,796	76,126	192	2,621	3.1
Pressboard	Tons (long)	6	947	2	106	2.4
Folding boxes	Tons (long)	1,000	51,696	148	5,687	1.3
Toilet paper	Tons (long)	200	17,318	11	389	2.4
Hide leather: soles	Pounds	238,605	66,206	164,544	7,534	6.1
Upper leather: calf and kip	Square feet	462,395	80,744	53,873	1,284	7.3
Upper leather: goat	Square feet	181,405	36,106	37,708	1,476	5.1
Upholstery leather	Square feet	42,578	6,231	46,157	1,715	3.9
Glove leather: sheep and goat	Square feet	96,009	8,948	36,579	1,107	3.1
Machinery belting: leather	Pounds	7,653	10,903	3,116	714	6.2
Threads: rubber	Pounds	5,415	2,551	2,083	317	3.1
Reclaimed rubber	Pounds	266,785	11,774	14,119	165	3.8
Hose: rubber	Pounds	93,594	24,390	15,949	760	5.5
Tubing: rubber	Pounds	13,608	2,236	2,054	114	3.0
Tyres, outer: motor car and aeroplane	Number	48,511	321,859	6,223	10,685	3.9
Tyres, inner: motor car and aeroplane	Number	47,781	44,453	4,473	1,071	3.9
Belting: rubber	Pounds	48,363	32,299	13,402	1,422	6.3
Valves, washers, rings, etc.: rubber	Pounds	5,168	2,106	2,939	237	5.1
Boots: rubber	Pairs	3,029	5,534	2,292	462	9.1

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Table 3.8 - continued from previous page

desc	*unit*	*us_q*	*us_v*	*uk_q*	*uk_v*	*uvr*
Shoes: rubber	Pairs	47,196	31,931	23,160	1,580	9.9
Fabrics: rubberized	Square yards	71,346	20,059	19,150	832	6.5
Gloves: rubber	Dozens Pairs	1,288	2,857	91	72	2.8
Water bottles: rubber	Dozens	580	2,496	245	226	4.7
Natural dyestuff: logwood	Pounds	8,706	744	1,064	15	6.1
Natural dyestuff: fustic	Pounds	1,360	100	6,350	71	6.6
Tanning: quebracho	Pounds	81,226	1,404	27,014	129	3.6
Tanning: other	Pounds	321,604	5,184	114,094	574	3.2
Naphtha	Gallons (UK)	180,612	13,223	4,118	185	1.6
Tar oils	Gallons (UK)	906	194	96,264	1,880	11.0
Acids: acetic	Tons (long)	45	5,455	11	327	3.9
Acids: nitric	Tons (long)	22	2,143	15	237	6.0
Acids: sulphuric	Tons (long)	3,326	31,908	599	1,958	2.9
Sulphates: aluminium	Tons (long)	311	7,748	88	375	5.9
Sulphates: alums	Tons (long)	23	1,457	8	54	8.7
Ammonia: liquor	Tons (long)	20	1,235	44	264	10.1
Bleaching material: calcium oxide	Tons (long)	35	909	55	278	5.1
Chloroform	Pounds	1,799	324	741	104	1.3
Sulphates: copper	Tons (long)	24	2,002	35	447	6.4
Ether: ethyl	Pounds	7,915	1,305	3,833	104	6.1
Compressed gas: sulphur dioxide	Pounds	24,628	1,170	7,437	38	9.3
Iodine	Pounds	200	238	133	26	6.1
Iodides: other	Pounds	45	104	41	16	6.0
Acetates: lime	Tons (long)	23	826	1	7	3.1
Sulphates: magnesium	Tons (long)	34	1,117	11	79	4.4
Magnesium compounds: other	Tons (long)	7	883	11	195	7.4
Mercury compounds: other	Pounds	733	739	571	110	5.2
Alcohols: methyl	Gallons (UK)	15,784	5,076	2,709	212	4.1
Iodides: potassium	Pounds	433	572	325	83	5.2
Sulphates: potassium	Tons (long)	2	157	2	14	7.8
Potassium compounds: other	Pounds	4,491	359	19,566	262	6.0
Carbonates: sodium	Tons (long)	2,349	57,580	1,102	6,852	3.9
Chromates: sodium	Tons (long)	38	4,763	6	197	3.9
Phosphates: sodium	Tons (long)	118	6,552	4	53	4.2
Sulphates: sodium	Tons (long)	263	5,303	97	224	8.7
Sodium compounds: other	Tons (long)	694	17,125	166	1,799	2.3
Tartrates: potassium	Pounds	3,855	642	426	15	4.7
Chlorides: tin	Pounds	16,118	4,151	1,691	98	4.4
Charcoal	Tons (long)	219	3,052	7	51	1.9
Arsenic compounds: other	Tons (long)	43	6,496	2	43	5.7
Acetates: butyl	Pounds	41,354	3,687	5,726	190	2.7
Sulphur	Tons (long)	42	1,650	18	113	6.3
Sulphonated oils	Tons (long)	15	3,378	9	172	11.3
Carbons	Tons (long)	86	6,460	6	120	3.6
Resins, synthetic	Pounds	88,521	15,770	30,442	1,224	4.4
Cellulose: acetate, benzyl and pyroxylin	Pounds	23,736	18,669	739	122	4.8
Buttons: casein	Gross	10,823	3,856	2,263	489	1.6
Buttons: mother-of-pearl	Gross	20,618	7,348	194	46	1.5
Fertilisers: superphosphates	Tons (long)	1,730	19,778	338	825	4.7
Fertilisers: nitrogenous	Tons (long)	3,751	93,092	542	2,620	5.1
Fertilisers: bone meal	Tons (long)	50	1,414	29	150	5.5
Fertilisers: other	Tons (long)	120	3,358	538	3,011	5.0
Glue and size	Tons (long)	184	22,724	45	913	6.1
Gelatine	Tons (long)	11	8,199	6	482	9.1
Glycerin: crude	Pounds	24,043	2,366	41,440	569	7.2
Glycerin: refined	Pounds	118,727	12,973	14,000	288	5.3
Soap: intermediate product	Pounds	3,665	270	37,072	356	7.7
Soap: soft	Pounds	84,227	5,842	42,000	390	7.5

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Table 3.8 - continued from previous page

desc	*unit*	*us_q*	*us_v*	*uk_q*	*uk_v*	*uvr*
Soap: bar	Pounds	1,144,554	51,812	600,880	7,078	3.8
Soap: toilet	Pounds	352,976	53,325	73,584	2,473	4.5
Soap: shaving	Pounds	12,868	7,816	3,584	453	4.8
Soap: abrasive	Pounds	233,587	7,688	51,408	381	4.4
Soap: powder	Pounds	722,166	53,029	239,456	3,641	4.8
Soap: flakes and chips	Pounds	458,935	36,329	95,088	1,804	4.2
Soap: liquid	Pounds	22,593	1,523	5,600	64	5.9
Paints: paste, white lead	Pounds	169,630	12,937	54,992	735	5.7
Paints: colors and pigments	Pounds	1,507,754	87,012	115,808	1,894	3.5
Bone-, carbon- and lampblack	Pounds	389,573	15,454	6,272	64	3.9
Paints: water and calcimines	Pounds	125,165	5,298	72,800	742	4.2
Paints: paste, other	Pounds	87,085	10,331	100,128	1,417	8.4
Varnishes and lacquers	Gallons (UK)	59,270	91,427	11,250	4,260	4.1
Thinners and driers	Gallons (UK)	17,022	14,569	1,526	424	3.1
Oils: cotton seed	Tons (long)	495	91,849	137	3,455	7.4
Oils: linseed	Tons (long)	216	43,272	104	2,451	8.5
Cake and meal: cotton seed	Tons (long)	1,441	54,023	437	1,955	8.4
Cake and meal: linseed	Tons (long)	420	13,387	158	1,275	3.9
Tallow: unrefined	Tons (long)	197	27,008	25	571	6.0
Tallow: refined	Tons (long)	33	4,915	13	381	5.0
Acids: stearic	Tons (long)	12	2,777	10	306	7.6
Refined petroleum: kerosene	Gallons (UK)	34,687	1,224	32,037	482	2.3
Refined petroleum: gasoline	Gallons (UK)	15,409,358	1,023,578	145,385	4,374	2.2
Refined petroleum: lubricating oil	Gallons (UK)	1,061,147	186,534	11,871	298	7.0
Refined petroleum: gas oil	Gallons (UK)	2,255,829	85,550	44,559	652	2.6
Refined petroleum: fuel oil	Gallons (UK)	1,483,868	60,983	130,925	1,169	4.6
Explosives: high explosives	Pounds	270,018	30,196	43,232	1,770	2.7
Explosives: blasting powder	Pounds	35,153	2,148	17,024	391	2.7
Dextrine	Pounds	29,493	1,591	19,376	135	7.7
Washing and scouring materials	Pounds	52,723	4,169	70,784	690	8.1
Ink: printers'	Pounds	150,585	32,561	54,096	2,356	5.0
Coke	Tons (long)	4,151	32,510	12,636	9,971	9.9
Building bricks	Thousands	2,293	25,495	7,174	15,376	5.2
Glass: beer bottles	Gross	1,197	3,708	1,272	897	4.4
Glass: mineral water bottles	Gross	1,822	6,373	409	306	4.7
Glass: liquor bottles	Gross	6,095	22,983	1,035	864	4.5
Glass: other bottles and jars	Gross	27,794	75,204	7,658	3,395	6.1
Glass: milk bottles	Gross	2,124	10,980	688	638	5.6
Glass: tubing	Pounds	27,302	3,666	3,830	194	2.7
Cement	Tons (long)	12,596	113,505	5,949	8,791	6.1
Gypsum	Tons (long)	1,117	13,529	265	517	6.2
Concrete: irrigation	Tons (long)	816	10,735	141	431	4.3
Concrete: paving materials	Tons (long)	49	243	911	1,363	3.3
Concrete: roofing tiles	Tons (long)	38	862	408	805	11.4
Concrete: blocks and bricks	Tons (long)	1,126	7,360	871	1,737	3.3
Ferro-manganese	Tons (long)	237	20,220	75	696	9.2
Spiegeleisen	Tons (long)	95	2,145	21	100	4.7
Ingots	Tons (long)	211	9,473	673	4,314	7.0
Steel castings, direct	Tons (long)	362	67,442	62	2,398	4.8
Steel blooms, billets and slabs	Tons (long)	4,043	133,158	1,683	10,862	5.1
Sheet and tinplate bars	Tons (long)	2,566	75,799	1,804	9,298	5.7
Wire rods	Tons (long)	821	35,980	375	3,124	5.3
Steel bars	Tons (long)	2,960	187,357	111	1,728	4.1
Flats, strips and hoop	Tons (long)	834	45,405	904	8,662	5.7
Stainless steel, bars, rods, etc.	Tons (long)	13	7,639	7	743	5.2
Scrap bars	Tons (long)	16	874	13	79	8.5
Structural steel	Tons (long)	2,367	160,085	513	3,640	9.5
Steel plates, 1/8 in. / 3/16 in.	Tons (long)	1,145	58,894	97	824	6.1
Steel plates, 3/16 in. and over	Tons (long)	413	19,887	855	6,842	6.0

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Table 3.8 - continued from previous page

desc	*unit*	*us_q*	*us_v*	*uk_q*	*uk_v*	*uvr*
Steel plates, under 1/8 in.	Tons (long)	3,086	181,966	715	8,385	5.0
Stainless-steel plates and sheets	Tons (long)	12	9,148	4	536	5.8
Rails and railway material	Tons (long)	877	39,112	627	5,805	4.8
Tyres and axles	Tons (long)	112	10,951	85	1,679	4.9
Iron and steel pipes and fittings	Tons (long)	663	35,315	672	7,122	5.0
Black plates (tinning)	Tons (long)	371	27,410	148	1,747	6.2
Tin plates	Tons (long)	1,692	175,730	603	11,545	5.4
Terne plates	Tons (long)	191	16,593	14	231	5.4
Ingots: copper	Tons (long)	26	4,935	27	883	5.7
Plates and sheets: copper	Tons (long)	83	26,143	35	2,004	5.5
Rods: copper	Tons (long)	99	22,387	73	2,840	5.8
Tubes: copper	Tons (long)	30	12,039	19	1,362	5.4
Ingots: brass	Tons (long)	66	14,381	33	1,187	6.0
Plates and sheets: brass	Tons (long)	130	42,335	47	2,622	5.8
Rods: brass	Tons (long)	84	23,894	67	2,902	6.5
Tubes: brass	Tons (long)	43	16,626	12	1,023	4.4
Castings: brass	Tons (long)	46	19,156	25	2,416	4.3
Ingots: aluminium	Tons (long)	43	16,154	32	2,642	4.6
Castings: aluminium	Tons (long)	22	17,924	16	2,183	5.9
Ingots: lead	Tons (long)	116	11,429	96	1,428	6.7
Plates and sheets: lead	Tons (long)	15	2,309	79	1,448	8.1
Plates, sheets and rods: nickel	Tons (long)	20	14,113	18	3,031	4.1
Solder: tin	Tons (long)	35	16,720	16	1,605	4.7
Ingots: tin	Tons (long)	2	2,712	35	7,606	5.0
Ingots: zinc	Tons (long)	28	3,044	66	982	7.4
Plates and sheets: zinc	Tons (long)	45	8,131	14	348	7.1
Ingots: anti friction metal (white base)	Tons (long)	10	4,982	5	783	3.2
Ingots: type metal	Tons (long)	25	4,234	10	302	5.3
Gold leaf	Sheets	43,062	1,188	25,600	114	6.2
Copper wire in coils	Tons (long)	19	5,986	73	3,797	6.0
Safety razors	Dozen	668	3,524	263	349	4.0
Safety razor, blades	Dozen	103,449	17,733	42,180	1,319	26.9
Locomotives: non-regular	Number	0	1,002	0	239	9.5
Tractors	Number	2	5,028	10	1,358	15.4
Road rollers	Number	0	576	1	262	7.0
Boilers	Number	16	9,066	49	3,160	9.0
Generators, A.C.: under 2,000 kW	Number	2	1,086	2	260	4.2
Generators, A.C.: over 2,000 kW	Number	0	10,694	0	656	5.9
Generators, D.C.	Number	1	862	11	683	19.0
Motors, fractional: under 1 h.p.	Number	7,777	36,980	282	703	1.9
Power transformers	Number	109	21,335	83	2,517	6.5
Vacuum cleaners	Number	1,112	24,191	409	3,286	2.7
Ignition magnetos	Number	396	5,264	71	284	3.3
Incandescent light bulb	Number	630,724	60,981	118,707	3,689	3.1
Radio apparatus: receiving sets	Number	5,570	129,109	1,724	10,463	3.8
Radio apparatus: tubes	Number	78,348	30,991	11,777	2,215	2.1
Electricity meters	Number	1,166	13,466	1,389	2,499	6.4
Clocks: complete	Number	13,072	19,733	731	653	1.7
Clocks: movements	Number	955	1,274	223	108	2.8
Watches: complete, jeweled	Number	1,326	18,882	47	71	9.4
Watches: complete, nonjeweled	Number	8,612	8,236	169	36	4.5
Watches: watchcases	Number	1,446	2,597	357	239	2.7
Matches: safety	Thousands	36,816	4,112	17,986	957	2.1

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Table 3.8 - continued from previous page

desc	*unit*	*us_q*	*us_v*	*uk_q*	*uk_v*	*uvr*
Matches: strike-anywhere	Thousands	249,600	19,877	60,847	3,314	1.5
Pianos: complete	Number	61	11,628	51	1,242	7.9
Pianos: player, complete	Number	0	60	0	13	3.2
Organs: complete	Number	0	1,438	0	222	2.6
Wind instruments (except accordians)	Number	111	3,126	3	22	3.4
Tennis rackets: complete	Number	368	803	504	495	2.2
Tennis rackets: frames, unstrung	Number	170	474	228	146	4.4
Golf clubs: complete	Number	1,665	4,406	588	350	4.4
Golf balls	Dozens	1,539	3,975	916	509	4.6
Tennis balls	Dozens	521	1,264	1,077	428	6.1
Gloves: crisket/baseball and boxing	Pairs	891	1,162	276	67	5.4
Footballs	Number	973	910	360	100	3.4
Skates	Pairs	3,210	3,344	108	25	4.5
Private cars	Number	3,213	1,752,794	327	48,255	3.7
Taxicabs	Number	2	2,914	0	124	4.4
Busses: designed to seat not more than 20 passengers	Number	1	1,410	0	50	2.0
Busses: designed to seat over 20 and not more than 32 passengers	Number	2	13,420	0	295	5.3
Busses: designed to seat over 32 passengers	Number	1	12,346	0	612	5.8
Trucks: capacity not exceeding 1.5 short tons (30 cwts.)	Number	470	227,393	34	4,253	3.9
Trucks: capacity exceeding 1.5 short tons (30 cwts.)	Number	35	43,809	14	4,393	4.0
Ambulances	Number	0	589	0	76	5.5
Chassis: private cars	Number	41	13,453	22	3,278	2.2
Chassis: busses	Number	1	785	4	3,107	1.5
Chassis: trucks	Number	152	71,702	0	14	2.0
Bodies: private cars	Number	2,083	351,682	134	5,234	4.3
Bodies: busses	Number	11	10,015	5	2,897	1.7
Bodies: trucks	Number	174	23,880	50	1,941	3.5
Trailers	Number	23	15,919	5	576	6.3
Car parts: internal-combustion engine	Number	69	6,583	142	2,996	4.5
Car parts: axles, including shafts	Number	1,874	58,326	180	1,080	5.2
Car parts: spark plugs	Number	87,051	17,176	5,386	451	2.4
Bicycles	Number	657	12,060	1,987	6,664	5.5
Ships, boats, etc.: over 5 tons	Number	0	25,837	1	11,001	4.7
Airplanes	Number	1	17,242	2	4,602	5.0
Aircraft engines	Number	3	12,610	3	3,918	3.4
Railway carriages	Number	0	7,552	0	990	7.8

3.B Input unit value ratios

Table 3.9: Input UVRs, US and UK (1935)

description	*quantity unit*	*United States* *quantity* (x,000)	*United States* *value* ($,000)	*United Kingdom* *quantity* (x,000)	*United Kingdom* *value* (£,000)	*uvr* ($/£)
Cotton: raw	Pounds	2,478,538	324,420	1,282,970	37,476	4.5
Waste: cotton	Pounds	75,442	8,156	130,880	2,252	6.3
Yarn: cotton	Pounds	133,206	47,503	983,679	46,881	7.5
Staple fibre: rayon	Pounds	2,452	1,157	6,829	405	8.0
Yarn: rayon	Pounds	18,926	10,773	22,499	3,279	3.9
Yarn: woollen	Pounds	1,089	1,030	1,306	142	8.7
Wool: raw	Pounds	95,930	20,629	529,036	30,870	3.7
Wool: recovered	Pounds	57,186	12,528	59,113	1,566	8.3
Tops	Pounds	66,084	51,490	182,500	16,610	8.6
Yarn: wool	Pounds	31,630	14,856	44,105	3,325	6.2
Cotton: raw	Pounds	12,512	2,039	5,140	174	4.8
Waste: cotton	Pounds	7,802	875	9,649	190	5.7
Yarn: cotton	Pounds	57,118	18,410	39,532	2,312	5.5
Yarn: silk	Pounds	478	877	337	119	5.2
Staple fibre: rayon	Pounds	240	60	278	23	3.0
Yarn: rayon (continuous filament)	Pounds	250	161	2,373	347	4.4
Yarn: staple rayon	Pounds	1,487	1,273	113	18	5.4
Waste: silk	Pounds	4,218	965	3,062	266	2.6
Silk: raw	Pounds	28,896	44,990	3,672	1,544	3.7
Yarn: cotton	Pounds	12,185	5,011	20,584	1,469	5.8
Yarn: woollen	Pounds	502	622	294	47	7.7
Yarn: worsted	Pounds	587	678	435	73	6.9
Cotton: short staple	Pounds	8,020	1,141	8,318	148	8.0
Silk: thrown	Pounds	2,639	4,999	350	233	2.8
Yarn: spun silk	Pounds	5,434	7,924	348	208	2.4
Yarn: rayon (continuous filament)	Pounds	139,875	88,720	38,724	5,983	4.1
Staple fibre: rayon	Pounds	3,457	1,352	3,032	185	6.4
Flax	Pounds	7,769	2,142	3,584	157	6.3
Flax: tow	Pounds	3,355	593	13,888	344	7.1
Hemp: soft	Pounds	2,129	277	14,336	262	7.1
Yarn: flax	Pounds	1,275	942	14,381	807	13.2
Jute: raw	Pounds	135,764	5,077	381,472	2,696	5.3
Waste: jute	Pounds	18,516	399	13,888	37	8.1
Yarn: cotton	Pounds	170,368	67,472	62,345	4,062	6.1
Yarn: wool	Pounds	47,412	45,904	60,630	8,479	6.9
Yarn: silk	Pounds	17,702	39,727	2,665	1,483	4.0
Yarn: rayon	Pounds	54,721	32,770	21,346	3,197	4.0
Yarn: cotton	Pounds	11,612	5,936	16,505	1,255	6.7
Yarn: silk	Pounds	165	338	83	42	4.0
Yarn: rayon	Pounds	689	413	2,968	364	4.9
Hard hemp: Manila	Pounds	75,927	3,136	79,038	545	6.0
Hard hemp: Sisal	Pounds	158,834	4,922	60,861	436	4.3
Hard hemp: New Zealand	Pounds	71	4	2,699	16	8.7
Yarn: cotton	Pounds	7,563	1,841	21,728	655	8.1
Iron ore	Tons (long)	36,458	169,156	14,982	7,415	9.4
Limestone	Tons (long)	6,567	9,126	1,746	492	4.9
Cinder and scale	Tons (long)	2,535	4,917	474	330	2.8
Dolomite	Tons (long)	834	1,235	253	198	1.9
Scrap: iron and steel	Tons (long)	1,012	8,192	276	462	4.8
Pig iron	Tons (long)	18,040	268,153	4,506	13,029	5.1
Ferro-alloys	Tons (long)	477	44,142	148	2,679	5.1
Scrap: iron and steel	Tons (long)	11,387	129,755	4,461	12,054	4.2

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Table 3.9 - continued from previous page

desc	*unit*	*us_q*	*us_v*	*uk_q*	*uk_v*	*uvr*
Ingots: steel	Tons (long)	251	7,480	473	2,912	4.8
Blooms, billets and slabs: steel	Tons (long)	3,977	118,347	1,592	9,379	5.1
Sheets: steel	Tons (long)	212	10,265	984	5,283	9.0
Pig iron	Tons (long)	855	14,768	1,447	5,134	4.9
Scrap: iron and steel	Tons (long)	562	5,783	645	1,676	4.0
Lead	Tons (long)	0	97	1	15	12.5
Solder: tin	Tons (long)	6	3,522	10	2,264	2.5
Black plates: iron and steel	Tons (long)	57	4,650	171	1,800	7.8
Sheets: iron and steel	Tons (long)	166	12,082	135	1,649	5.9
Tinplate	Tons (long)	1,405	151,322	214	4,171	5.5
Copper, brass and bronze	Tons (long)	1	315	18	886	7.6
Shapes: iron and steel	Tons (long)	17	1,040	4	95	2.7
Wire rods: iron and steel	Tons (long)	611	27,054	394	3,372	5.2
Copper	Tons (long)	62	13,446	53	1,901	6.0
Brass	Tons (long)	2	758	3	179	5.7

Chapter 4

The Great Escape

Technological Lock-in vs Appropriate Technology in Early Twentieth Century British Manufacturing*

4.1 Introduction

As discussed in the previous chapters, the US forged ahead of Britain in terms of productivity levels from the late nineteenth century onwards. Britain's, as well as other European countries' falling behind during the nineteenth century and their inability to catch-up has traditionally been explained by local circumstances; i.e. factor and resource endowments as well as demand patterns.[1] In Europe, natural resources were scarce, whereas skilled labor was in ample supply. This provided European producers with an incentive to economize on fixed capital in the form of machinery.[2] In contrast, the US was well endowed with natural resources, while skilled labor was relatively expensive. Therefore, machinery was substituted for skilled labor, resulting in a capital-intensive production process. Furthermore, as the American demand for goods was more homogenous, manufacturers could standardize production methods and implement high throughput systems, thereby raising productivity levels.[3] This advantage was denied to European producers, who faced heterogeneous markets characterized

*. Parts of this chapter appeared previously in J. Veenstra and P. Woltjer, "The Yanks of Europe? Technological Change and Labor Productivity in German Manufacturing, 1909–1936," in *XVIth World Economic History Congress* (Stellenbosch, 2012), 1–29.

1. Habakkuk, *American and British Technology in the Nineteenth Century*.

2. Temin, "Labour Scarcity in America," 162; A. Field, "On the Unimportance of Machinery," *Explorations in Economic History* Vol. 22 (1985): 379.

3. Broadberry, "Technological Leadership and Productivity Leadership in Manufacturing," 291.

by a demand for customized goods.[4] Thus, local circumstances determined the initial choice of technology. Technological progress was subsequently directed toward the particular technological path a country had chosen, leading to lock-in effects.[5] Particularly David puts path dependency center stage when explaining the evolution of distinctive transatlantic systems of production. In this view, a major shift in technology applied, for any country, is only feasible if relative factor prices change dramatically.

As illustrated in chapter 3, the transatlantic productivity gap – which had evolved to a ratio of around 2:1 by 1900 – continued to widen up to the 1950s.[6] Broadberry argues that this lack of productivity convergence reflected the persistence of distinct industrial technologies in Europe and the United States.[7] European producers continued to pursue a crafts-based production system, losing both productivity and technological leadership to the American system of mass-production that, up to the 1970s, proved to be technologically more progressive. In the period since the 1970s, according to Broadberry, craft production once again became more progressive and technological leadership reverted back to Europe. For the case of British and American industrial performance, the premise of the coexistence of two distinct industrial systems is strengthened by time-series evidence which finds that, after 1870, the productivity gap between both countries was non-stationary and divergent.[8] This non-stationarity suggests that industrial productivity followed different, independent paths, which precludes an important role for technology transfer.

As pointed out by Bowden and Higgins, the problem with the above interpretation is that it is essentially static. "It traces the misfortunes of the interwar years to technical choices made in the previous century which depended upon specific supply- and demand-side factors. It presumes that demand can be taken as given and that supply adjusted accordingly, rather than allowing for the possibility that supply-side changes may create new demands. It lacks the possibility of change, of adaption to different conditions and changes in resource constraints."[9] Basu and Weil developed an alternative analytical framework which illustrates that, regardless of static differences in factor and resource endowments or demand patterns, countries have the potential to rapidly converge in terms of labor-productivity levels if they successfully adopt the

4. Note that recently Hannah has argued against the hypothesis of large heterogeneous European markets and small-scale production, illustrating his point with evidence of relatively low transportation costs and integrated markets in Europe prior to 1914. Hannah, "Logistics, Market Size, and Giant Plants in the Early Twentieth Century."

5. David, *Technical Choice, Innovation and Economic Growth*, 66.

6. Broadberry, *The Productivity Race*, 3; Broadberry and Irwin, "Labor Productivity in the United States and the United Kingdom," 265.

7. Broadberry, "Technological Leadership and Productivity Leadership in Manufacturing," 292.

8. Greasley and Oxley, "Comparing British and American Economic and Industrial Performance," 184.

9. Bowden and Higgins, "British Industry in the Interwar Years," 383–4.

leaders' production technologies.[10] They emphasize the fact that technological change appears to be biased toward the capital-intensive technologies and that spillovers occur only in a limited range of technologies. Countries operating on a technical level far below the range of the world's technology leaders are thus likely to fall behind in terms of productivity growth. This will eventually induce them to adopt more capital-intensive production techniques in order to benefit from knowledge spillovers. The mechanics behind this type of technology transfer are also regarded by Aghion and various other scholars who argue that countries distanced far away from the productivity frontier can catch-up by applying an investment-based growth strategy, provided that the necessary capabilities and resources – mainly primary and secondary education – are available.[11] The speed at which countries are likely to converge is not only dependent upon the size of the technology gap and the rate of capital deepening (their savings rate), but is constrained by the effects of learning by doing and other barriers that raise the cost of adopting a higher level of technology as well.[12] These ideas build upon Abramovitz' concept of 'social capabilities' and Gerschenkron's 'appropriate' economic institutions to encourage technology adoption.[13]

Several recent studies have found empirical evidence that strongly supports Basu and Weil's appropriate-technology hypothesis.[14] These studies rely on a novel framework, the data envelopment analysis (DEA), that emphasizes the role of technology and the potential for technology transfer; factors that, thus far, have received little attention in the empirical convergence literature.[15] They confirm the importance of localized innovation – i.e. technological improvement that is confined to a particular mix of capital and labor, or more generally, is restricted to a range of similar technologies – and stress the finding that global technological change is decidedly biased toward capital-intensive production techniques, both for the period prior to and following

10. Basu and Weil, "Appropriate Technology and Growth."

11. P. Aghion, "Higher Education and Innovation," *Perspektiven der Wirtschaftspolitik* Vol. 9 (2008): 31; D. Acemoglu, "Directed Technical Change," *Review of Economic Studies* 69 (2002): 39; J. Vandenbussche, P. Aghion, and C. Meghir, "Growth, Distance to the Frontier and Composition of Human Capital," *Journal of Economic Growth* 11 (2006): 98.

12. R. Barro and X. Sala-I-Martin, "Technological Diffusion, Convergence, and Growth," *Journal of Economic Growth* 2 (1997): 1–27.

13. A. Gerschenkron, *Economic Backwardness in Historical Perspective: A Book of Essays* (Cambridge: Belknap Press of Harvard University Press, 1962), 113, 116; M. Abramovitz, "Catching-up, Forging Ahead and Falling Behind," *Journal of Economic History* 46 (1986): 387.

14. Kumar and Russell, "Technological Change, Technological Catch-up, and Capital Deepening"; B. Los and M. Timmer, "The 'Appropriate Technology' Explanation of Productivity Growth Differentials: An Empirical Approach," *Journal of Development Economics* 77 (2005): 517–531; Timmer and Los, "Localized Innovation and Productivity Growth in Asia"; F. Caselli and W. Coleman, "The World Technology Frontier," *American Economic Review* 96 (2006): 499–522; R. Allen, "Technology and the Great Divergence: Global Economic Development Since 1820," *Explorations in Economic History* 49 (2012): 1–16.

15. A. Bernard and C. Jones, "Technology and Convergence," *Economic Journal* 106 (1996): 1037–8.

the Second World War.[16] This strong capital-bias in conjunction with the exceptionally progressive nature of technological change during the early twentieth century – as stressed by authors such as Gordon and Field – is likely to have induced European entrepreneurs to increase their rate of capital deepening and adopt American production techniques.[17] This hypothesis is in stark contrast to the static David model of divergent transatlantic technological paths, adhered to by Broadberry for the twentieth century.

In this chapter I adopt the DEA framework and apply it to the case of productivity and technology convergence in Britain and the United States. The aim of this chapter is threefold. First, I want to confirm whether technological change in manufacturing during the first half of the twentieth century was localized (i.e. whether the assumption of factor neutrality can be rejected). The second aim is to show empirically whether British industries continued to innovate along their own labor-intensive productivity path (David's model) or, if they actively sought to adopt American techniques, by accumulating physical capital, to benefit from the rapid technological change at the capital-intensive side of the production frontier (Basu and Weil's model). The third and last aim of this chapter is to quantify the effects of technological change, capital deepening, and barriers to technological diffusion on labor productivity growth at the industry level. This will provide a novel view of the dynamics behind the trans-Atlantic labor-productivity differentials during the early twentieth century.

For this purpose I have constructed a new set of internationally comparable, industry-specific output, employment and capital measures, spanning the period 1899 to 1939. As convergence in terms of labor productivity driven by technology diffusion typically occurs at the level of products or industries rather than at the total economy level, I retain a highly disaggregate level of analysis on the basis of original census data.[18] This allows me to study technological change and transfer at the industry level, which sets my study apart from previous studies that typically maintained a strong macroeconomic viewpoint.[19]

In this chapter my primary interest lies in the measurement of technology convergence rather than its causes. Not because I think that a search for the causes of the patterns of efficiency is unimportant, but because I feel uncovering the pattern comes first. My findings should be interpreted as being complementary to existing explanations in either the neoclassical or endogenous-growth literature that model the

16. A. Atkinson and J. Stiglitz, "A New View of Technological Change," *Economic Journal* 79 (1969): 574; Kumar and Russell, "Technological Change, Technological Catch-up, and Capital Deepening," 529; Allen, "Technology and the Great Divergence," 4–5.
17. Gordon, "US Economic Growth Since 1870: One Big Wave?"; Field, "The Most Technologically Progressive Decade of the Century."
18. Timmer and Los, "Localized Innovation and Productivity Growth in Asia," 48.
19. Kumar and Russell, "Technological Change, Technological Catch-up, and Capital Deepening"; Allen, "Technology and the Great Divergence."

impediments to technology transfer, as well as traditional explanations of the British growth experience during the early twentieth century. The model and the decomposition exercise is explained in section 4.2. In this section I will also, briefly, discuss the construction of the data set. Section 4.3 presents the main results, which are considered in light of the current debate on British technological change in section 4.4. Section 4.5 concludes.

4.2 Methodology and data

For my study of productivity dynamics in Britain and the United States I apply a data envelopment analysis (DEA) and perform the decomposition technique recently proposed by Kumar and Russell.[20] The DEA approach allows me to estimate a global production frontier which represents the various 'best practice' production techniques observed for the entire feasible range of input combinations. By tightly enveloping data points with linear segments using mathematical programming methods, the structure of the frontier can be revealed without imposing a specific functional form on either technology or deviations from it.[21] Because of its non-parametric nature, the DEA naturally allows for any form of localized technical change, an important feature in my framework.[22] This approach also lends itself more readily to the decomposition of productivity growth as, in contrast to traditional growth-accounting exercises, it distinguishes between both the effects of (global) technological change and relative efficiency change.[23] In later sections I will show that efficiency loss, i.e. the movement away from the frontier, is a crucial factor in explaining the British growth dynamics during the early twentieth century.

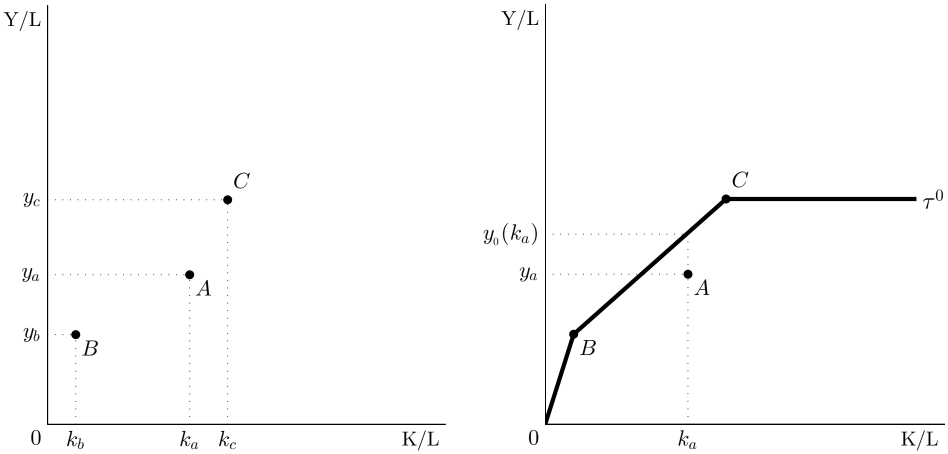
Data Envelopment Analysis

Figure 4.1 depicts a basic example of a DEA involving three producers which use two inputs (capital K and labor L) to produce a single output (Y). Assuming constant returns-to-scale, I can represent the world production frontier in $\langle k, y \rangle$ space, where y is labor productivity (Y/L) and k is capital intensity (i.e. individual production techniques, K/L).

As noted above, the frontier (τ) for the observations in figure 4.1 is formed as linear combinations of observed extremal activities or, following Salter's definition, 'best-

20. Kumar and Russell, "Technological Change, Technological Catch-up, and Capital Deepening."
21. R. Färe, S. Grosskopf, and K. Lovell, *Production Frontiers* (Cambridge: Cambridge University Press, 1994), 12.
22. Los and Timmer, "The 'Appropriate Technology' Explanation of Productivity Growth Differentials," 522.
23. Färe, Grosskopf, and Lovell, *Production Frontiers*, 13.

Figure 4.1: Illustration of data envelopment



(**a**) observations (**b**) frontier

practice' activities.[24] An observation is said to be a best-practice activity if it exhibits full efficiency in the Koopmans sense, who defined an activity as technologically efficient if increasing any output or decreasing any input is possible only by decreasing some other output or increasing some other input.[25] As illustrated in appendix 4.C, the identification of these fully efficient observations can be reduced to a basic linear programming problem in the form of a distance function.[26]

Of the three observations in this example, only B and C are classified as best-practice techniques. The frontier is formed by tightly enveloping these two fully efficient observations with linear segments, as illustrated in the right-hand panel of figure 4.1. The frontier is thus a subset of all feasible techniques that attain the highest labor productivity for the capital intensity levels they correspond to.[27]

The panel on the right-hand side of figure 4.1 also shows that the last remaining observation (A) is located below the frontier. Observation A's vertical distance to the frontier indicates the potential for labor-productivity increase. Farrell shows that this distance can be interpreted as a measure of technical efficiency.[28] In figure 4.1, the ratio of A's observed productivity y_a to the optimal productivity level at A's capital-intensity $y_0(k_a)$ represents the Farrell efficiency index.

24. Salter, *Productivity and Technical Change*.
25. T. Koopmans, "Efficient Allocation of Resources," *Econometrica* 19 (1951): 460.
26. R. Färe et al., "Productivity Growth, Technical Progress, and Efficiency Change in Industrialized Countries," *American Economic Review* 84 (1994): 68–9.
27. Timmer and Los, "Localized Innovation and Productivity Growth in Asia," 52.
28. G. Debreu, "The Coefficient of Resource Utilization," *Econometrica* 19 (1951): 273–292; M. Farrell, "The Measurement of Productivity Efficiency," *Journal of the Royal Statistical Society* 120 (1957): 253–290.

Decomposition

The frontier approach can be used in a decomposition of total-factor productivity (TFP), a process described by Kumar and Russell as 'growth accounting with a twist'.[29] They break down TFP growth into two components: (1) technological catch-up, and (2) technological change. They characterize the first component as movements toward (or away from) the frontier, as countries adopt best practice technologies and reduce (or exacerbate) technical and allocative inefficiencies. The second component reflects shifts in the global production frontier, determined conceptually by the state-of-the-art, potentially-transferable, technology.[30] To decompose labor productivity growth, rather than TFP growth, the effects of capital accumulation can be added, which reflect movements along the frontier.[31]

To illustrate this decomposition, I have extended the example of figure 4.1 to include a second period. As shown in the left panel of figure 4.2, the example now includes six observations: the three original observations from period 0 and three new observations for period 1. To form the new frontier, I again utilize the distance functions to locate the fully efficient observations among the six in the sample. These observations are then enveloped by linear segments. Both the new frontier as well as the original period 0 frontier are shown on the right-hand side of figure 4.2.[32]

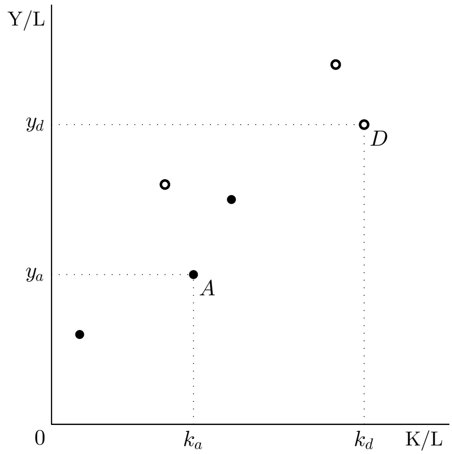
The panel on the right-hand side of figure 4.2 also displays two inefficient observations (A and D) which represent the same producer at time 0 and 1 respectively. Labor-productivity change, between these observations A and D, can be decomposed according to equation (4.1) below

$$\frac{y_d}{y_a} = \underbrace{\left(\frac{y_d}{y_1(k_d)} \Big/ \frac{y_a}{y_0(k_a)}\right)}_{\text{efficiency}} \cdot \underbrace{\left(\frac{y_1(k_a)}{y_0(k_a)} \cdot \frac{y_1(k_d)}{y_0(k_d)}\right)^{0.5}}_{\text{technological change}} \cdot \underbrace{\left(\frac{y_0(k_d)}{y_0(k_a)} \cdot \frac{y_1(k_d)}{y_1(k_a)}\right)^{0.5}}_{\text{accumulation}} \tag{4.1}$$

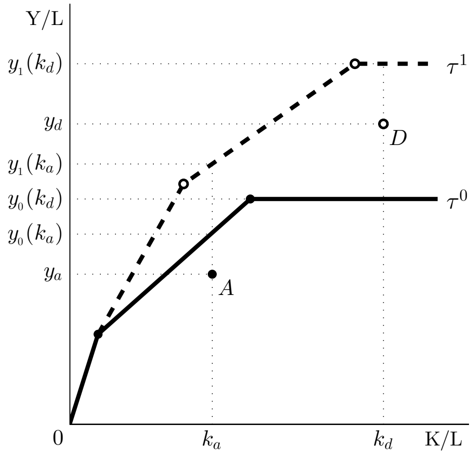
The first right-hand side factor measures the change in the Farrell efficiency index. A value larger than 1 represents an increase in the level of technical efficiency over time; hence, I denote this as the *efficiency* component. The second factor, *technological change*, measures the increase in labor productivity as a result of a shift in the frontier. Since the vertical shift of the frontier can be observed both at capital intensity k_a as well as k_d, I adopt a 'Fisher ideal' decomposition and report the geometric average of

29. Kumar and Russell, "Technological Change, Technological Catch-up, and Capital Deepening," 529.
30. ibid., 528.
31. Timmer and Los, "Localized Innovation and Productivity Growth in Asia," 50.
32. Note that the period 1 frontier (τ^1) in figure 4.2 consists of observations from both the first and the last period. As a result, the frontier will only shift outward as I will discuss below.

Figure 4.2: Illustration of growth decomposition



(a) observations



(b) frontiers

the two measures. The last factor, which I label *accumulation*, is a Fisher index of the potential change in labor productivity resulting from a shift in the capital-labor ratio. This component represents the average productivity gains or losses as a result of the movement along both frontiers.

Extensions to the basic model

For my analysis, I have made a number of additions to the basic framework described by Kumar and Russell. First, I adopt an 'intertemporal' approach, in line with the empirical analysis of Los and Timmer.[33] Instead of estimating the frontier at time *t* based solely on observations from this period, I also include all observations prior to period *t* in the production set. Los and Timmer argue that there are two important reasons to adopt the intertemporal approach:

> "First, because the production frontier is constructed sequentially, it can never shift inward and hence 'technological regress' cannot occur. The possibility of 'technological regress' seems awkward and hard to defend from a knowledge perspective on technology, as it would involve 'forgetting'. Second, a crucial element in the [Basu and Weil] model is the possibility for countries to use knowledge that was generated by technology leaders

33. Los and Timmer, "The 'Appropriate Technology' Explanation of Productivity Growth Differentials"; for a discussion of the time component in data envelopment analysis see, H. Tulkens and P. Vanden Eeckaut, "Non-parametric Efficiency, Progress and Regress Measures for Panel Data: Methodological Aspects," *European Journal of Operational Research* 80 (1995): 474–499.

> in the past. Labor-productivity levels of past technology leaders should be attainable for latecomers."[34]

A potential problem is that frontier techniques observed for the first year in my sample, 1907, could be dominated by unobserved combinations in the past. In that case, part of what would be interpreted as frontier movements would in fact be assimilation of knowledge associated with these unobserved appropriate techniques. To accommodate this problem, I extended the data set backwards by 8 years and included two additional periods for the US, 1899 and 1904 respectively.

Secondly, I address the issue of aggregation. So far, the level of aggregation in the frontier analysis literature has been highly macroeconomic. Kumar and Russell for the post-WWII period and Allen for the nineteenth and early twentieth century, for instance, rely on a global production frontier for the total economy.[35] Bernard and Jones show that sectoral measures of productivity growth and convergence can look very different from aggregate results.[36] Convergence in terms of labor productivity driven by technology diffusion typically occurs at the level of products or industries, rather than at the total economy level. As pointed out by Timmer and Los, "Convergence at the industry level might not be reflected in macroeconomic statistics when countries differ in their industrial composition or experience different patterns of structural change."[37] Broadberry indeed observes substantial differences in the sectoral composition between Great Britain and the US for the early twentieth century.[38] Hence, I focus solely on manufacturing, which has the biggest scope for technology spillovers. In addition, I break up the manufacturing sector into twenty-seven industry-groups and estimate a separate global production frontier for each.

Data

For the analysis of transatlantic labor-productivity differentials between 1907 and 1930, I have constructed a new data set of industry-specific real value added, employment and capital statistics. My panel observes ten benchmark years for the US (spanning the period 1899 to 1939) and two years for Great Britain (1907 and 1930). In addition, I also included two benchmark years for Germany (1907 and 1936).[39] The set thus includes data for the three greatest industrial nations of the early twentieth

34. Los and Timmer, "The 'Appropriate Technology' Explanation of Productivity Growth Differentials," 522–3.
35. Kumar and Russell, "Technological Change, Technological Catch-up, and Capital Deepening"; Allen, "Technology and the Great Divergence."
36. Bernard and Jones, "Technology and Convergence," 1043.
37. Timmer and Los, "Localized Innovation and Productivity Growth in Asia," 48.
38. Broadberry, *The Productivity Race*, 63–73.
39. The results for Germany are discussed in a separate working paper; see, Veenstra and Woltjer, "The Yanks of Europe?"

century, covers approximately 105 separate industries and overall consists of nearly 1,500 observed input-output combinations.

The capital data is based on horsepower statistics, a proxy of the stock of machinery and equipment. I focus on machinery rather than the total capital stock for two reasons: (1) the horsepower statistics are available at a highly disaggregate level allowing me to study productivity at the individual industry level and (2) De Long and Summers show that there is a much stronger association between investment in equipment and machinery and economic growth than any other other component of investment.[40] Innovations are embodied in machinery to a far greater degree than is the case for buildings and intermediate inputs.

The basic source for US industries is the *Census of Manufactures*, while the primary British data is taken from the First and Fourth *Census of Production*.[41] German data is drawn from multiple industrial surveys, statistical yearbooks, employment censuses as well as the archival records of the 1936 *Industrial Census*.[42] This section will, very briefly, describe the basic methods behind the construction of the data set. A full description of sources and methods can be found in appendices 4.A and 4.B.

As a first step in the construction of my data set, I reclassified the industrial data for all three countries and all years to the 1945 US Standard Industrial Classification (SIC).[43] Generally, an industrial classification groups establishments primarily engaged in the same line, or similar lines, of economic activities. In the case of manufacturing this is either defined in terms of the products made (demand side) or the processes of manufacture used (supply side).[44] The SIC scheme places primary em-

40. B. DeLong and R. Summers, "Equipment Investment and Economic Growth," *Quarterly Journal of Economics* 106 (1991): 445–502.

41. United States Department of Commerce: Bureau of the Census, "Manufactures"; United States Department of Commerce: Bureau of the Census, "Manufactures," in *Fourteenth Census of the United States Taken in the Year 1920*, vol. VIII (Washington D.C.: United States Government Printing Office, 1923); United States Department of Commerce: Bureau of the Census, "Manufactures: General Report," in *Fifteenth Decennial Census of the United States* (Washington D.C.: United States Government Printing Office, 1933); United States Department of Commerce: Bureau of the Census, "Manufactures: Statistics by Subjects"; Board of Trade, *Final Report on the First Census of Production of the UK*; Board of Trade, *Final Report on the Fourth Census of Production of the United Kingdom (1930)* (London: H.M. Stationery Office, 1933–5).

42. Kaiserlichen Statistischen Amte, "Statistisches Jahrbuch für das Deutschen Reich," chap. Gewerbe in (Berlin, 1912), 52–133; Kaiserlichen Statistischen Amte, "Vierteljahrshefte zur Statistik des Deutschen Reichs: Ergänzungsheft," chap. Ergebnisse der Deutschen Produktionserhebungen in, vol. 22, 3 (Berlin, 1913); Kaiserlichen Statistischen Amte, "Vierteljahrshefte zur Statistik des Deutschen Reichs," chap. Ergebnisse der deutschen Produktionserhebungen in, vol. 23, 2 (Berlin, 1914); Statistischen Reichsamt, *Gewerbliche Betriebsählung* (Berlin: Verlag fur Sozialpolitik, Wirtschaft und Statistik, 1933); Reichsamt fur Wehrwirtschaftliche Planung, *Die Deutsche Industrie. Gesamtergebnisse der amtlichen Productionsstatistik. Schriftenreiche des Reichsamt fur wehwritschaftliche Planung, Heft 1* (Berlin: Verlag fur Sozialpolitik, Wirtschaft und Statistik, 1939); Statistischen Reichsamt, *Wirtschaft und Statistik* (Berlin: Verlag fur Sozialpolitik, Wirtschaft und Statistik, 1938).

43. For an overview of the SIC, see United States Department of Commerce: Bureau of the Census, "Statistics by Industry," in *Census of Manufactures 1947* (Washington D.C.: United States Government Printing Office, 1949), 862–914.

44. Kendrick, *Productivity trends in the United States*, 405–6.

phasis on the latter, whereas the original, pre-war, British, German and American classifications rely heavily on the former. The supply-side grouping of businesses – i.e. the categorization according to the way in which inputs are transformed into outputs, mainly depending on the technology used – fits neatly into the DEA framework.

To make the British output data directly comparable to the US, I relied on the price conversion factors introduced in chapters 2 and 3 of this dissertation.[45] The industry level conversion factors, or Purchasing Power Parities (PPP), were calculated on the basis of producer prices, using the procedures first set out by Paige and Bombach and extensively delineated in the work of van Ark.[46] To make the German data comparable to the US, I turned to two new, as yet unpublished, benchmark studies for 1907/09 and 1935/36 based on the same methodology.[47] These PPPs enabled me to convert British and German value added into nominal dollar values, both prior to and following the First World War.

Nominal value added in dollars for all three countries was then converted to constant prices (with a 1929 base) by applying US price deflators at the industry level. I calculated deflators on the basis of Fabricant's indices of physical- and nominal-output series.[48] Subsequently, I reclassified these deflators to fit the SIC, and incorporated the modifications and extensions to the indices of production proposed by Kendrick.[49] Lastly, I expressed the employment measure in terms of hours worked and adjusted my capital measure to exclude the power of electric motors run by current generated in the same establishment. The adjustment to the measure of the capacity of horsepower was made in order to prevent the duplications of motors effectively driving the same machinery. The necessity of the hours adjustment has been stressed in chapter 3. There I recount the substantial drop in the average hours of work for the interwar period, particularly for the US.

45. Note that the interwar Anglo-American benchmark refers to the year 1935, whereas the British production figures for this study are based on the 1930 census returns. To convert British value added to 1935 dollars I have taken the output-price changes between 1930 and 1935 for Great Britain into account. For Britain, I extrapolated the 1935 PPPs to a 1930 base using price deflators taken from the work of Feinstein. See appendix 4.B for further details; Feinstein, *National Income, Expenditure and Output of the United Kingdom*.

46. Paige and Bombach, *A Comparison of National Output and Productivity*; Ark, *International Comparisons of Output and Productivity*, 25–52.

47. The price data for the German interwar benchmark was collected from the American 1935 Census of Manufactures as well as the German Industrial Census of 1936. The sources and methods used were identical to those described in the recent 1935/36 British-German benchmark by Fremdling et al. and the 1935 British-American benchmark by de Jong and Woltjer reproduced in chapter 3. For the pre-war benchmark, US price data was again taken from the 1909 Census of Manufactures. German, manufacturing-wide production censuses did not become available until after the First World War. For the early benchmark, data is obtained from industrial surveys, which reported output and prices for a sample of industries between 1907–1912. See, Fremdling, Jong, and Timmer, "British and German Manufacturing Productivity Compared"; Jong and Woltjer, "Depression Dynamics"; Veenstra and Woltjer, "The Yanks of Europe?"

48. Fabricant, *The Output of Manufacturing Industries*, 123–321, 605–39.

49. Kendrick, *Productivity trends in the United States*, 416–21, 467–75. See appendix 4.A for further details.

My data set thus includes a single measure of output (value added in constant 1929 dollars) and two inputs (hours worked and horsepower capacity), similar to the example discussed above. I also assume constant returns-to-scale throughout this chapter.[50] As previously noted, I estimate a separate frontier for twenty-seven industry groups. These industry groups are referred to as two-digit industries; a denotation which indicates their level of aggregation as being one step above the three-digit level, the level of detail of my data set. In the estimation of the frontiers I pool all the three-digit observations belonging to the same two-digit industry, implicitly assuming that these observations share a common production function.[51]

4.3 Results

The main findings of this chapter can be summarized in three points. First, for the first half of the twentieth century technological change at the frontier was decidedly non-neutral and biased toward capital-intensive production techniques. Because of this bias labor productivity grew fastest for capital-intensive techniques. If frontier technology was freely available to follower countries, the latter had a clear incentive to adopt capital-intensive production techniques. Secondly, in terms of capital-intensity levels, British manufacturing converged on the US between 1907 and 1930, creating a large growth potential. Thirdly, Great Britain did not take full advantage of the growth potential it had created. Despite the process of rapid capital deepening, low levels of efficiency stood in the way of Britain catching-up in terms of labor-productivity levels. These findings are more in line with Basu and Weil's model of localized technological change than David's concept of technical lock-in.

Biased technological change

In his analysis of the diverging Anglo-American labor-productivity gap during the nineteenth century, David argues that the initial choice of technology – being either capital-intensive for the US, or labor-intensive for Europe – led to distinctive rates

50. Färe et al. show that the flexible nature of the DEA would allow me to relax the constant-returns-to-scale assumption, this does come at a cost of greatly increased data requirements, however. A sensitivity check on the basis of variable returns-to-scale, which can be found in appendix 4.E, demonstrates that this assumption does not significantly alter my findings. I therefore feel confident using it. See, Färe, Grosskopf, and Lovell, *Production Frontiers*, 32–7.

51. Note that the two-digit classification used for the frontier estimation differs moderately from the US Standard Industrial Classification. At the two-digit level the 1945 SIC only distinguishes between twenty industries. I separated a number of these two-digit SIC industries as the assumption of a common production function appeared to be invalid. In these cases I estimated more than one separate frontier for that respective group. A notable example is the *chemicals and allied products* industry. Appendix 4.E provides a more extensive description of the selection of frontiers, as well as a sensitivity check on the assumption of a shared production function at the two-digit level.

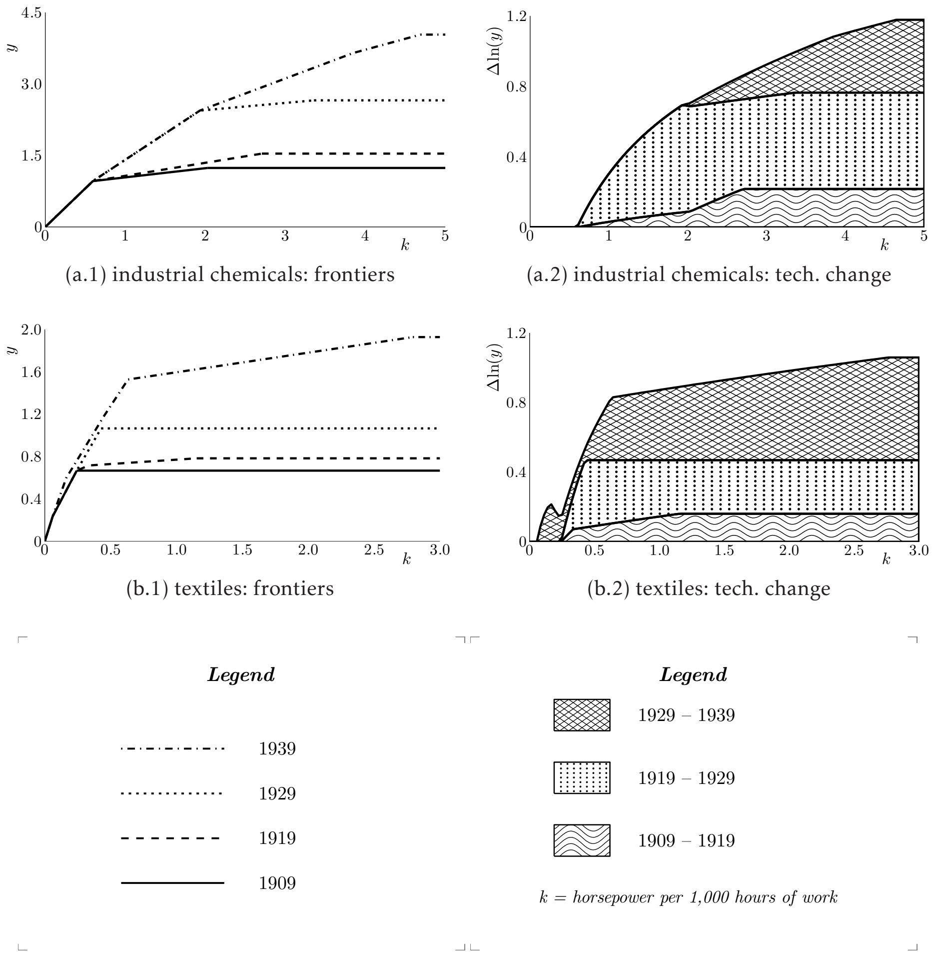
of technical progress across the Atlantic, as the effect of technological advances for a particular input mix was not automatically transferred to other technologies and was essentially 'localized' to a specific capital-labor ratio.[52] In similar vein, Basu and Weil argue that, although technology is freely available to all and instantly transferred, a country may nonetheless refrain from using a new technology until it reaches a level of development at which this technology would be 'appropriate' to its endowments.[53] They emphasize the fact that technological change appears to be strongly biased toward the capital-intensive technologies. Consequently, countries operating on a technical level far outside the range of the world's technology leader are likely to fall behind in terms of productivity growth, as they are unable to benefit from the technological change at the capital intensive side of the production frontier. This will eventually induce the follower countries to adopt more capital-intensive production techniques to take advantage of the technology improvements made by the leader countries in the past.[54]

Although both these models rely on the same concept of localized technological change, David's analysis is essentially static whereas the Basu and Weil model incorporates a dynamic element. The Basu and Weil model allows for the possibility of countries to escaping the technological lock-in trap which inevitably follows from David's model. As pointed out by Bowden and Higgins, the problem with David's interpretation is that it traces the misfortunes of the interwar years to technical choices made in the previous century and does not allow for the possibility of either supply- or demand-side changes.[55] Basu and Weil on the other hand show that, regardless of static differences in factor and resource endowments or demand patterns, countries have the potential to rapidly converge in terms of labor-productivity levels if they successfully adopt the leaders' production technologies.[56]

Several empirical studies have confirmed the existence of factor-biased technical change – which stands at the heart of the Basu and Weil model – in pre-WWII manufacturing industries at the *aggregate* level.[57] In this section I will corroborate the existence of this bias for the early twentieth century at the *disaggregate* level, particularly for those industries closely associated with the Second Industrial Revolution. The bias in technological change, for the period between 1909 and 1939, is illustrated in figure 4.3 for two of my twenty-seven industries.[58] For both industries I include a plot

52. David, *Technical Choice, Innovation and Economic Growth*; Broadberry, "Technological Leadership and Productivity Leadership in Manufacturing," 295.
53. Basu and Weil, "Appropriate Technology and Growth," 1027.
54. Timmer and Los, "Localized Innovation and Productivity Growth in Asia," 49–50.
55. Bowden and Higgins, "British Industry in the Interwar Years," 383–4.
56. Basu and Weil, "Appropriate Technology and Growth."
57. Salter, *Productivity and Technical Change*, 133; Allen, "Technology and the Great Divergence," 6.
58. Graphs for all industries are shown in appendix 4.D.

Figure 4.3: Global technological change (1909–1939)



(a.1) industrial chemicals: frontiers

(a.2) industrial chemicals: tech. change

(b.1) textiles: frontiers

(b.2) textiles: tech. change

of the global production frontiers on the left-hand side, in line with the example in figure 4.2. In addition, on the right-hand side I graph the log change in potential labor productivity as a result of the shift in the global frontier over time. This technological change is plotted for varying levels of capital intensity.

The top-most panels of figure 4.3 show that, for the industrial chemicals industries, technological progress is strongly biased toward capital-intensive forms of production. Technological change for producers in this industry operating at a capital intensity level of 4 horsepower per 1,000 hours of work was between 50 and 100 percent higher than for those producers operating at a capital-intensity level of 2 or less. Below a level of 0.5, technological change was absent or negligible. The picture that emerges for this industry corroborates Basu and Weil's proposition that innovation is primarily carried out by the technology leader and does not shift the production frontier as a whole. Instead, only the section of the production frontier in the direct vicinity of the innovators' combination of production factors shifts upward as a result of the technological change.

The textiles industries, on the other hand, exhibited factor-neutral technological change, as evidenced by the stable relation between capital intensity and technological change in the lower-right panel. For textiles, the increase of labor productivity as a result of technological advances were only marginally greater at a capital-intensity level of 3 compared to a level of 1. The discussion in appendix 4.D shows that, for the majority of manufacturing industries, technological change exhibited a strong bias toward capital-intensive production techniques. Notable exceptions to this rule (i.e. textiles, leather and the foods sector) stress the importance of a highly disaggregated analysis when studying technological change and the diffusion of technology, however. I will return to this issue in the sectoral decomposition of the Anglo-American productivity gap below.

Over time, the bias of technological change shifted further toward the right into the more capital-intensive range of production techniques. Between 1929 and 1939 producers in the industrial chemicals sector operating at a capital-intensity level below 2 did not experience any further gains in labor productivity resulting from technological progress. This trend can be observed for the majority of manufacturing industries during the early twentieth century and continued after the war.[59] Generally, I observe the most rapid rate of technological change between 1919 and 1929, represented in figure 4.3 by the area of the dotted surface. For the US, technological change contributed over 3.4 percentage points to overall manufacturing labor-productivity growth annually between 1919 and 1929.[60] This was considerably higher than the 1.3 points experienced during the 1910s and the 1.6 points I observe for the 1930s. The technologically progressive nature of the interwar period is also stressed by authors such as Gordon and Field.[61] The wide range of new technologies and practices, as well as the strong capital bias in technological development created a clear incentive for British entrepreneurs to increase the rate of capital deepening and adopt American production techniques.

59. Allen, "Technology and the Great Divergence," 5.

60. The contribution of technological change for the sub-periods is calculated on the basis of the *technological change* factor in equation (4.1), which represents a Fisher index of the log change in labor productivity as a result of the shift in the global production frontier.

61. Gordon, "US Economic Growth Since 1870: One Big Wave?"; Field, "The Most Technologically Progressive Decade of the Century."

Table 4.1: Decomposition of labor-productivity growth, total manufacturing, US and GB

	annual average growth rate, in ln%			
	total	*accumu-lation*	*tech. change*	*effi-ciency*
United States (1909–1929)	3.1	0.7	2.2	0.2
Great Britain (1907–1930)	1.9	1.7	1.4	-1.2
Difference (US-GB)	*1.2*	*-1.0*	*0.8*	*1.4*

Source: see section 4.2.

Aggregate decomposition

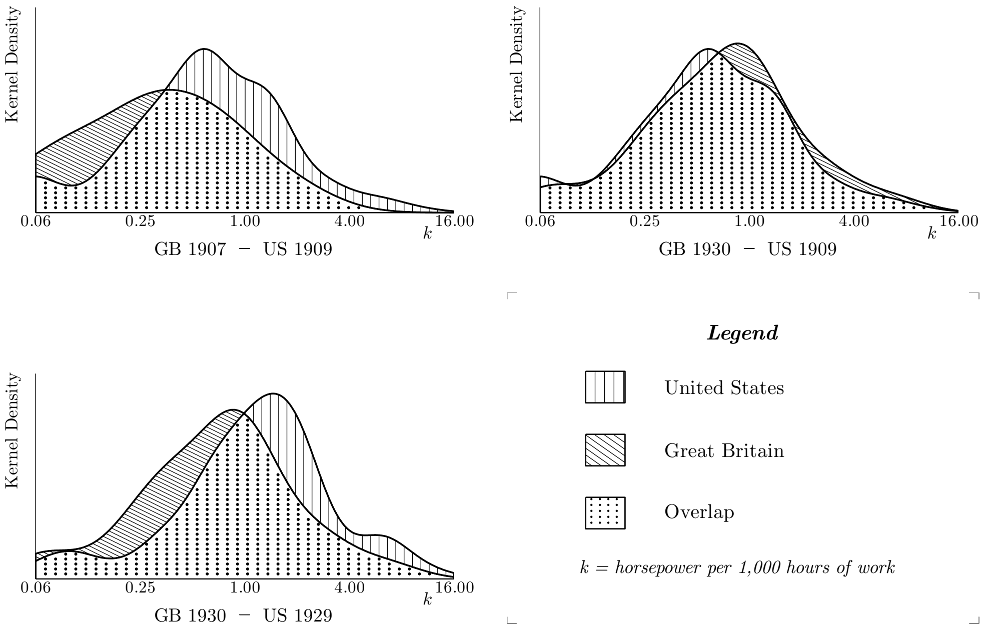
Table 4.1 reports the average annual growth rate of aggregate manufacturing productivity for the US between 1909 and 1929 and Great Britain between 1907 and 1930. Labor-productivity growth is broken down into the contribution of capital accumulation, technological change and efficiency change, following the Kumar and Russell procedure illustrated in equation (4.1).[62] The last row of table 4.1 lists the difference between the average British and American rates of growth, essentially a decomposition of the gap in Anglo-American labor-productivity growth into the aforementioned components.

Both American and British performance was relatively strong during this period.[63] Nonetheless, labor productivity growth in the US was considerably faster, and overall the productivity gap increased by approximately 1.2 percent per year. As table 4.1 illustrates, the drivers behind the widening of the productivity gap were relatively slow technological change and general efficiency decline in British manufacturing industries. However, the process of capital deepening proceeded at a considerably higher rate in Britain, in turn decelerating the divergence process. Below, I will argue that the substantial accumulation component represents a general movement of a number of modern British industries toward American production techniques, thus partially bridging the technology gap that arose during the nineteenth century. In the short run,

62. For the total manufacturing estimates I weight technological change for all the underlying observations by their value added shares. In this aggregation I included only the observations from the start- and end-year for growth decomposition.

63. Note that the annual productivity increases listed in table 4.1 correspond closely to the growth rates reported by Feinstein for the UK and Kendrick for the US. British manufacturing output rose, on average, by 1.2 percent per year between 1907 and 1930, while total employment and the average annual hours-of-work declined by 0.1 and 0.6 percentage points respectively. American manufacturing output grew by 4.2 percent annually between 1909 and 1929, while the number of persons engaged increased by 1.6 percent and average hours decreased by 0.9 percent during this period. See, Feinstein, *Statistical Tables of National Income, Expenditure and Output of the UK*, T111–3, 129, 131; Kendrick, *Productivity trends in the United States*, 465–6. For a discussion on working hours see chapters 2 and 3.

Figure 4.4: Distribution of capital intensity, US and GB



the gainful impact of this capital-deepening process on British industrial performance was weakened by a drop in efficiency, most likely resulting from learning-by-doing effects and other barriers that raised the cost of adopting a higher level of technology.

Figure 4.4 illustrates the bridging of the transatlantic technology gap. It presents the distribution of manufacturing employment over available production techniques (proxied by machine intensity) for both the US and Great Britain. During the first half of the twentieth century, capital-intensity levels were converging and by 1930 Britain had already surpassed the 1909 American level. In 1907, British manufacturing employed, on average, 0.48 horsepower per 1,000 hours of work in manufacturing. This ratio rose to 1.14 by 1930. In 1909, the American capital-intensity level was 0.98, which increased to 1.81 by 1929. The upper-right panel of figure 4.4 illustrates that, not only were the average levels merging, the interwar British distribution of employment over capital-intensity levels (i.e. production techniques) mirrored that of the US in 1909. Whereas the British distribution of production techniques before the First World War showed a distinct pattern – with a vastly greater percentage of workers engaged in capital-extensive industries and lacking the characteristic American tail of very capital-intensive production – the shape and range of the distribution of production techniques for Great Britain resembled that of the US halfway the interwar period. Prior to the Second World War, Britain still trailed the US by almost two decades, yet overall dissimilarities between production techniques used in American and British manufacturing industries disappeared to a large extent. While at the turn of the century both countries tracked different technical paths, such a distinction is no longer evident for the interwar period. The comparatively high rate of capital deepening in British manufacturing implies that initial conditions did not stand in the way of capital-intensive production.

The rapid rate of capital deepening explains nearly all of British labor-productivity growth between 1907 and 1930, as shown in table 4.1. The accumulation component for Britain is considerably larger than for its American counterpart, reflecting both a faster rise in capital intensity and the greater gains from capital deepening at lower levels of horsepower per hour worked; the latter affirms the standard assumption of diminishing returns to capital-intensity. The general move of British industries toward American production techniques also led to an increase in the rate of technological change, since aggregate technological change generally exhibits a strong bias toward capital-intensive technologies, as discussed above. Nonetheless, the British rate of technological progress was still substantially slower than I observe for the US during this period. Lagging technological change in Great Britain remained a major contributor to the widening of the transatlantic productivity gap.

The final component in the Kumar and Russell decomposition, efficiency change, represents the residual of the observed rise in labor productivity and the potential labor-productivity growth – the latter resulting from both capital accumulation and technology change. Timmer and Loss illustrate that the efficiency change can be interpreted as the result of learning-by-doing and indicates the extent to which a country has exhausted the potential of a particular technology.[64] In addition to these 'pure' efficiency gains or losses, the residual efficiency term for aggregate manufacturing also includes the effects of structural change. Table 4.1 reports a small efficiency gain for the US between 1909 and 1929, which can, for the most part, be attributed to a favorable shift in the employment structure of American manufacturing. Over the course of these two decades, labor was transferred from low-productive textile production toward chemicals and machinery fabrication. Generally, pure efficiency, or the relative vertical distance of American industries to the world-frontiers, remained unchanged.[65] British manufacturing experienced a similar shift in the employment struc-

64. Timmer and Los, "Localized Innovation and Productivity Growth in Asia," 52; see also, Basu and Weil, "Appropriate Technology and Growth"; Barro and Sala-I-Martin, "Technological Diffusion, Convergence, and Growth."

65. Note that, even though the US (as technology leader) dominated the world production frontier during the early twentieth century, I do observe several British and German observations that were located on the frontier, thus making it a truly 'global' frontier.

ture, boosting aggregate labor-productivity growth.[66] Nonetheless, the total efficiency component in table 4.1 for Britain is well below zero, thus suggesting a substantial decline in pure efficiency at the industry level. Between 1907 and 1930, British industries were thus unable to realize their full potential that came about through the process of rapid capital deepening and increases in technological change. Consequently, even though British manufacturing converged on the US in terms of capital-intensity levels, the Anglo-American productivity gap failed to narrow and, as is evident from table 4.1, even widened considerably during the interwar period.

Delayed catch-up

In contrast to the literature I do not view the lack of catch-up growth as a failure on the part of British entrepreneurs. Previous applications of the DEA-approach led to findings resembling mine. For a sample of Asian countries, in the period between 1975–1992, Timmer and Los find comparable gaps between potential and realized labor-productivity growth.[67] Timmer and Los' interpretation of the Asian growth experience is based on Basu and Weil's analytical framework and rests on a two-tiered approach to catch-up. Follower countries go through two sequential phases of development in order to close the gap to the frontier, as depicted in figure 4.5.

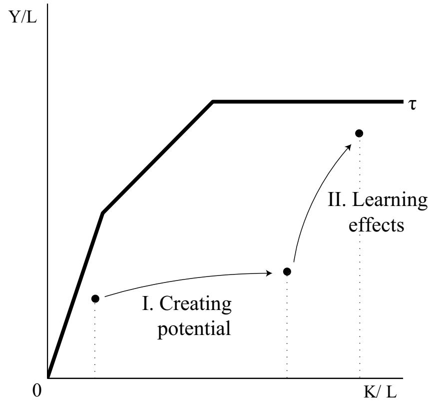
The initial phase of catch-up, the adoption of new production techniques through the accumulation of capital, involves an extensive transformation of the production process. This causes efficiency levels to deteriorate in the short run. Only after the economy has successfully adjusted to the new state and has 'learned' to operate the new technology at its full potential, can the labor-productivity gap to the frontier be narrowed. This adjustment process was referred to by David as 'learning-by-doing'.[68] The time lag between creating potential and the movement toward the frontier depends both on the scope of capital deepening and on the flexibility of the economy and its institutional arrangements. For the case of Britain this implies that the implementation problems that engineers and industrialists encountered in the 1920s and 1930s were not signs of failed industrialization. Instead, they were features of modernization and inextricably linked to the initial phase of catch-up growth.

66. In Great Britain there was a substantial outflow of labor from the textile, apparel and leather industries, which in 1907 held a share of 43 percent of manufacturing employment but which declined to 33 percent in 1930.

67. Particularly for Korea – the country that experienced one of the fastest rates of capital deepening – the relative distance to the global frontier increased over time. Overall, Korea grew 3.8 percentage point less than the 9.3 percent annual growth potential it had created. Instead of interpreting the negative efficiency component as a failure, Timmer and Los conclude that these findings suggest a possible sequence in which countries first create opportunities for growth by rapidly increasing capital intensities and only later start to benefit from technology spillovers. See, Timmer and Los, "Localized Innovation and Productivity Growth in Asia," 58, 60.

68. David, *Technical Choice, Innovation and Economic Growth*, 1–2.

Figure 4.5: Catch-up in two sequential steps



Sectoral decomposition

Although the above discussion reveals a clear pattern in the widening of the total manufacturing labor-productivity gap, it masks the underlying dynamics in the British-American convergence process through the aggregation of industries. Table 4.2 captures the average annual growth rate of British and American labor-productivity at the industry level.[69] British manufactures showed a comparatively strong performance in the textiles, apparel, leather, building materials and instruments industries.[70] These industries experienced relatively slow rates of technological progress and suffered less efficiency decline, which led to a comparatively modest increase of the Anglo-American labor-productivity gap. In contrast, labor-productivity levels diverged most in the industries closely associated with the Second Industrial Revolution; namely, transportation equipment, chemicals, petroleum and rubber. These 'modern' industries experienced exceptionally rapid rates of global technical advances and exhibited a strong bias toward uneven factor saving. During the early twentieth century, the acceleration in the (localized) technological change induced British entrepreneurs to adopt American-style, capital-intensive, production techniques, as evidenced by the greater accumulation component for most notably the transportation-equipment industry. As observed for aggregate manufacturing, the Anglo-American technological convergence (through the rapid British capital deepening) led to a substantial decline in efficiency levels in Great Britain for these modern industries.

69. The estimates in table 4.2 show labor productivity growth and its decomposition for the main industry groups within manufacturing. Appendix 4.F provides the results for the full breakdown of the manufacturing sector, including all SIC two-digit industries.

70. Note that the instrument-producing industries are part of the miscellaneous category in table 4.2. See appendix 4.F for a full breakdown of the manufacturing sector.

Table 4.2: Decomposition of labor-productivity growth, manufacturing industries, US and GB

	annual average growth rate, in ln%			
	total	*accumulation*	*tech. change*	*efficiency*
United States (1909–1929)	*3.1*	*0.7*	*2.2*	*0.2*
Food & tobacco	3.1	1.5	1.9	-0.3
Textiles & apparel	2.3	0.5	1.9	-0.1
Paper & printing	3.6	1.1	2.4	0.2
Chemicals & rubber	4.6	0.8	3.2	0.6
Building materials	3.3	0.4	2.4	0.5
Metals	2.5	0.4	2.0	0.2
Machinery	2.2	0.1	1.5	0.6
Transportation equipment	8.2	2.0	5.6	0.6
Miscellaneous	1.9	0.3	1.8	-0.2
Great Britain (1907–1930)	*1.9*	*1.7*	*1.4*	*-1.2*
Food & tobacco	1.8	2.3	1.2	-1.7
Textiles & apparel	2.5	1.2	1.6	-0.4
Paper & printing	2.5	3.3	1.2	-2.1
Chemicals & rubber	1.3	1.9	2.3	-2.9
Building materials	2.1	1.0	1.5	-0.4
Metals	0.7	1.1	1.3	-1.7
Machinery	0.5	0.5	0.4	-0.5
Transportation equipment	3.6	3.6	3.0	-3.0
Miscellaneous	1.3	3.0	0.5	-2.1
Difference (US-GB)	*1.2*	*-1.0*	*0.8*	*1.4*
Food & tobacco	1.3	-0.8	0.7	1.5
Textiles & apparel	-0.2	-0.7	0.2	0.3
Paper & printing	1.2	-2.3	1.2	2.3
Chemicals & rubber	3.3	-1.0	0.8	3.5
Building materials	1.2	-0.6	0.9	0.9
Metals	1.8	-0.7	0.7	1.9
Machinery	1.7	-0.4	1.1	1.1
Transportation equipment	4.6	-1.6	2.6	3.6
Miscellaneous	0.6	-2.6	1.3	1.9

Source: see section 4.2; May not sum to total due to rounding.

A marked example of the adoption of American-style, capital-intensive production techniques in Britain at the industry level is the chemicals sector. This sector encompasses the chemicals, petroleum, coal- and rubber-products industries which, during the early twentieth century, experienced an unprecedented rate of productivity growth. Between 1909 and 1929, American labor productivity in the chemicals sector grew by 4.6 percent annually, over 3 percentage points of which was derived directly from technological change. This technological change was strongly biased toward capital-intensive production techniques, as illustrated by the industrial-chemicals sector in figure 4.3. As British producers in the chemicals sector were initially operating on a technical level outside the range of the world's technology leader, the contribution of technological change to British productivity growth fell well short of that of the US, widening the Anglo-American productivity gap by 0.8 percent annually. Comparatively rapid British capital deepening in the chemicals sector more than offset the effects of technological change, however. Table 4.2 shows that the potential for growth in British chemicals – i.e. the sum of the technological change and accumulation components – actually surpassed that of its American counterpart. Yet, the shift toward more capital-intensive methods of production and the rapid technological change led to a deterioration of efficiency in Great Britain, preventing British chemical producers from realizing their full potential. Overall, the Anglo-American labor-productivity gap in this sector widened by 3.3 percent per annum. I observe similar dynamics in the other modern industries, particularly transportation equipment, but also electrical machinery, paper, printing and to a lesser degree metals. Again, I distinguish stronger technological change in the US, which was biased toward capital-intensive production techniques, coupled with considerably faster capital accumulation in Great Britain. Similarly, for these industries I also observe a severe deterioration in British efficiency levels.

For the textiles, apparel and building materials industries table 4.2 reveals a different pattern. Here, I do not observe the rapid decline in British efficiency levels. Moreover, for these industries the gap in the Anglo-American labor-productivity levels rose less than the manufacturing average. In the case of the textiles and apparel industries this gap even declined slightly over the course of these two decades. As a result of relatively slow, unbiased, technological change, British producers lacked the incentive to diverge from the original, labor-intensive technological path. This deterred them from adopting American production techniques as avidly as we saw for the modern industries. The dichotomy of technology paths is also evident in the foods sector. Even though the accumulation component for this British industry was relatively large, by 1930 the British capital intensity level in the foods sector was still well below the American level in 1909 (0.70 versus 1.12 respectively). In the production of food, as was the case for textiles, British industry was clearly operating on a different part of the technology frontier compared to their American competitors.

The traditional explanation of differences in factor endowments, which will affect all industries equally (at least in the case of the availability of labor), is unable to explain the apparent divide in the rate of adoption of American, capital-intensive production techniques across the different manufacturing sectors. The industry-specific rate and bias of technical progress provides a novel explanation why British entrepreneurs in the textiles and building materials, but also in the food industries, continued to track a labor-intensive path of production, whereas, at the same time, the producers of chemicals, printing and transportation equipment diverged from this path and actively sought to adopt new, capital-intensive, production techniques. The disaggregate decomposition above shows that only those British industries that experienced strongly biased technological change were drawn toward these more capital-intensive ways of production. Moreover, particularly those industries that diverged from their original technological path experienced a clear worsening of their relative technical efficiency. As noted in the previous section, the convergence in terms of capital intensity and production techniques led, in the short-run, to a widening of the Anglo-American labor-productivity gap. Regardless, the modern industries showed strong growth potential, the fruits of which could be reaped when the (initial) barriers to the successful adoption of the new production techniques were overcome and producers learned to operate the new technology at its full potential. In line with this reasoning, during the first two decades following the Second World War, the British manufacturing sector experienced significantly stronger trend growth than the US and the two countries gradually started to converge in terms of labor-productivity levels.[71]

4.4 Barriers to British productivity convergence

I am certainly not the first to study Europe's inability to close the transatlantic productivity gap during the first half of the twentieth century, and I consider the analysis applied in this chapter to be complementary to previous work discussing the constraints to British labor-productivity growth. The non-parametric growth decomposition presented in this chapter uncovers the large discrepancy between created growth potential and realized growth. In turn, the existing literature can provide a better understanding of the impediments to technological transfer and the causes behind the pronounced decline in efficiency within British manufacturing. Although it is not my

71. N. Crafts and T. Mills, "Europe's Golden Age: An Econometric Investigation of Changing Trend Rates of Growth," chap. 11 in *Quantitative Aspects of Post-War European Economic Growth*, ed. B. van Ark and N. Crafts (Cambridge: Cambridge University Press, 1996), 421.

intent to offer an exhaustive overview of the literature, I aim to link the key mechanisms of my model to the realities of interwar Britain.

The argument made by Broadberry is that Britain failed to adapt to the changing conditions of the interwar years and, in the face of different endowments and demand patterns, continued to pursue a crafts-based production system, losing both productivity and technological leadership to the American system of mass-production.[72] Consequently, Broadberry argues, British manufactures allowed relative productivity levels to fall, under-invested in new machinery (and hence production processes), failed to modernize its management, under-equipped its labor force with relevant skills and embodied a myriad of restrictive practices which prevented industry from realizing its potential.[73] Section 4.3 of this chapter presents a rather more dynamic view of British manufacturing. I show that a sizable part of British manufacturing was drawn toward the more capital-intensive, American ways of production and exhibited substantial growth potential. In this section I will illustrate that, in these key industries, British entrepreneurs did indeed introduce modern, mechanized production techniques, invested in continuous-flow manufacturing and adopted new techniques of managerial control. By confirming that Britain was successfully adapting to the rapidly changing environment, I can reject the premise that the entire manufacturing sector was locked into a separate technology path and prove that technology transfer did occur. I do argue however that, in the case of Britain, the adoption of modern production techniques was severely hampered by government intervention in an attempt to correct for market failures, the dominance of craft unions and pre-existing work practices that proved hard to displace. These institutional impediments explain why technological diffusion was not as widespread, and the convergence of technological paths did not occur as quickly as observed in the case of Germany for instance.[74]

Below, I discuss the impact of these institutions, both on the reluctance of British manufactures to move into the new, dynamic industries that emerged during the early twentieth century, as well as the relatively hesitant adoption of capital-intensive production techniques within some of these industries.

British technological change

To illustrate the introduction of mechanized production techniques in British manufacturing I once again turn to the transportation equipment industry. This industry experienced, as I illustrated in the previous section, exceptionally rapid rates of global

72. Broadberry, "Technological Leadership and Productivity Leadership in Manufacturing."
73. Bowden and Higgins, "British Industry in the Interwar Years," 384.
74. Ark, *International Comparisons of Output and Productivity*, 86–7; Crafts and Mills, "TFP Growth in British and German Manufacturing, 1950-1996," 650; Crafts, "British Relative Economic Decline Revisited," 22–3.

technical progress which exhibited a strong bias toward uneven factor saving. I argue that these technological advances induced British entrepreneurs to adopt American-style, capital-intensive production techniques in order to bridge the productivity gap that had arisen during the previous decades. The rapid capital deepening was reflected in a particularly large accumulation component, which, between 1907 and 1930, accounted for almost all of British labor-productivity growth in this industry. In the age of growing private motor ownership and 'Fordism', it was the motor vehicles industry that particularly stood out in terms of technological progress.[75] Yet it was also this industry where British engineers have been criticized for their failure to adopt American mass-production methods.[76] As argued by Bowden and Higgins, prior to the Second World War, Britain lacked a mass-market for automobiles as demand was limited to the middle and upper classes.[77] The British consumers placed a particularly high premium on the performance and quality of their motor vehicles and were less concerned with price constraints. Hence mass-production, as espoused by Fordism, was not a viable option for British producers.

Nonetheless, the interwar years did witness significant investment in the British motor vehicle industry. The fact that it was not Fordist does not invalidate it. The annual growth rate of total capital in the vehicle industry – which Matthews et al. estimate to have been 3.1 percent – was among the highest in British industry in the interwar years.[78] The 1920s and 1930s witnessed large investment programs undertaken by the major motor vehicle producers with the gradual introduction of mechanized production techniques, assembly lines and specialized machinery used to produce individual items on a continuous basis. British producers of motor vehicles were following the path set out by the American vehicle industry. In 1923, for example, a major investment program in continuous flow production began at Longbridge as a result of which this site became the first motor works in the country with a moving assembly line for the production of chassis and car bodies.[79]

These modernizations were not exclusively confined to the motor vehicle industry. During the First World War, in the industries essential to the war effort, scientific management techniques such as time-and-motion studies were applied in order to maximize output and efficiency. Machine tools were imported from the United States and installed in the factories where they were previously unknown. Automatic welding spread through the shipyards. Eichengreen notes that "the installation of automatic machinery allowed a growing number of operations to be undertaken by workers with

75. Field, *A Great Leap Forward*, 70.
76. Lewchuk, *American Technology and the British Vehicle Industry*.
77. Bowden and Higgins, "British Industry in the Interwar Years," 386–7.
78. Matthews, Feinstein, and Odling-Smee, *British Economic Growth, 1856–1973*, 241.
79. Bowden and Higgins, "British Industry in the Interwar Years," 386–7.

minimal training. In this way, British industry took a first tentative step down the road that led to modern mass-production as in the United States."[80]

The move toward capital-intensive production techniques was not apparent in all industries, however. The textiles industry proved to be highly reluctant to invest in new production techniques and technological change. In the previous section I showed that this industry experienced a relatively modest rate of unbiased technological progress and that both American and British producers were disinclined to invest in this industry. As a result, the technology gap, that had opened up during the nineteenth century, remained wide. In accordance with the Broadberry view, the two countries continued to track a different technological path in this industry. This is most obvious for cotton textiles, which was the focus of a case study by Lazonick.[81] Lazonick argued that the cotton textile industry failed to modernize by re-equipping with ring spinning and automatic looms. Whereas, during the interwar years, ring spinning capacity was the dominant spinning choice in the world, the British cotton textile industry still relied heavily on mule spinning. The relative importance of rings in the UK remained low at just around 23 percent.[82] Consequently, by this time a large proportion of British cotton spinning machinery had become technically obsolete. Sandberg argued that demand and relative factor costs were the main reasons why English spinners persisted with mules, rather than an aversion to new technology.[83]

The reluctance to adopt new production techniques is apparent for most traditional industries. My estimates indicate that industries such as building materials, clothing and textiles showed little or no sign of convergence in terms of capital intensity levels. Whereas newer industries, such as chemicals, petroleum, transportation equipment, and printing did exhibit rapid capital deepening and technological catch-up. The experience within these industry-groups was not uniform however; the capital deepening process in the transportation equipment sector, for instance, was primarily driven by investment in the motor vehicle and aircraft industries, while the more traditional shipbuilding and railway carriage trades continued to track a labor-intensive production path. In the case of the engineering sector, it was the electrical engineering industry that exhibited a high growth rate of its capital stock and witnessed a dramatic increase in the range of items produced.[84] Even though the transformation of British manufacturing was hesitant and mostly limited to the more dynamic new industries there was cause for cautious optimism. Eichengreen remarked:

80. Eichengreen, "The British Economy Between the Wars," 320–1.
81. W. Lazonick, "Production Relations, Labor Productivity, and Choice of Technique: British and U.S. cotton spinning," *Journal of Economic History* 41 (1981): 491–516.
82. Bowden and Higgins, "British Industry in the Interwar Years," 386.
83. L. Sandberg, "American Rings and English Mules: The Role of Economic Rationality," *Quarterly Journal of Economics* 83 (1969): 25–43.
84. Matthews, Feinstein, and Odling-Smee, *British Economic Growth, 1856–1973*, 241.

> "By the end of the 1930s some 250 British firms had adopted modern techniques of managerial control (including the multidivisional firm). Modern cost accounting had been installed, and top management was being professionalized. Spending on research and development tripled over the course of the decade. New products and processes proliferated, fueling hopes of the emergence of a 'development bloc' of modern industries."[85]

The 'new' industries

The role played by the new industries has been emphasized in the literature before.[86] Notably, Richardson ties the robust British growth performance experienced during the interwar period to these modern industries.[87] This view was backed by evidence of a revival of TFP growth during the 1930s, as well as a strong emphasis on the quality of modern investment and the structuring of British industry toward these growth-oriented sectors.[88] In addition, Richardson stresses the technical developments and the introduction of new processes, production methods and products in these industries, whose progress he considered to be largely interdependent. In the more recent historiography the growth performance of the British economy during the 1920s and 1930s and the role played by the new industries has been viewed more critically, however. Broadberry shows that structural change within manufacturing was not particularly pronounced during this period, while overall productivity growth was not especially fast.[89] Also, Crafts stresses the fact that productivity and TFP growth in the UK remained well below the standard set by US industries during the first half of the twentieth century.[90] As a result, on an hours-worked basis, the labor-productivity gap between Britain and the US in manufacturing continued to widen up to the 1950s.[91] The direct Anglo-American benchmark for 1935, discussed in chapter 3, also reveals that particularly the modern British industries (engineering, transportation equipment and chemicals) performed poorly in comparison to their American counterparts.

The poor productivity performance of particularly the new industries in Britain does not appear to favor the 'optimistic' interpretation by Richardson, nor does it ac-

85. Eichengreen, "The British Economy Between the Wars," 341.

86. Richardson, "The New Industries Between the Wars"; Richardson, "The Basis of Economic Recovery in the Nineteen-Thirties"; N. Buxton, "The Role of the 'New' Industries in Britain During the 1930s: A Reinterpretation," *Business History Review* 2 (1975): 205–222; S. Pollard, *The Development of the British Economy*, 3rd ed. (Baltimore: Edward Arnold, 1983); H. de Jong, *Catching Up Twice: The Nature of Dutch Industrial Growth During the Twentieth Century in a Comparative Perspective* (Berlin: Akademie Verlag, 2003), 108–9.

87. Richardson, "The Basis of Economic Recovery in the Nineteen-Thirties," 360–1.

88. Matthews, Feinstein, and Odling-Smee, *British Economic Growth, 1856–1973*; Pollard, *The Development of the British Economy*, 53.

89. S. Broadberry, "Unemployment in Interwar Britain: A Disequilibrium Approach," *Oxford Economic Papers* 35 (1983): 466–8.

90. Crafts, "British Relative Economic Decline Revisited," 21.

91. For further details see chapter 3.

Table 4.3: Decomposition of labor-productivity growth, new industries vs. old staples, US and GB

	annual average growth rate, in ln%			
	total	*accumulation*	*tech. change*	*efficiency*
United States (1909–1929)				
New industries	3.6	0.8	2.6	0.2
Old staples	2.5	0.4	2.0	0.1
Great Britain (1907–1930)				
New industries	1.8	2.5	1.7	-2.4
Old staples	1.7	1.2	1.3	-0.8
Difference (US-GB)				
New industries	*1.8*	*-1.7*	*1.0*	*2.5*
Old staples	*0.8*	*-0.8*	*0.7*	*0.9*

Source: see section 4.2; May not sum to total due to rounding.

cord well with the wave of modernization described above. However, as previously noted, TFP growth consist of both improvements in technology as well as efficiency with which the factors of productions are used.[92] My decomposition allows for the breakdown of TFP in both these components. In table 4.3 I recast the results from section 4.3 in terms of 'new industries' and 'old staples', in line with the distinction made by Richardson as well as Crafts.[93] This decomposition contrasts the strong growth potential of the new industries against the slower, yet almost fully realized potential in the old staples.

Table 4.3 confirms the fact that, in British manufacturing between 1907 and 1930, hourly labor productivity in the new industries grew slightly faster than in the old staples. In addition, it corroborates Crafts' claim that productivity growth in the British industries remained well below the standard set in the US and that, in international perspective, the old staples performed comparatively better than the new industries; as the latter lost considerable less ground to the American producers. The decomposition also reveals, however, that the potential for growth in the new British industries was substantially greater than was the case for the old staples. Capital accumulation alone was responsible for over 2.5 percent of annualized growth in the new industries,

92. N. Crafts, "Creating Competitive Advantage: Policy Lessons from History," chap. 2 in *The UK in a Global World: How Can the UK Focus on Steps in Global Value Chains That Really Add Value?*, ed. D. Greenaway (London: Centre for Economic Policy Research, 2012), 7.

93. H. Richardson, "Over-Commitment in Britain Before 1930," *Oxford Economic Papers* 17 (1965): 250; Crafts, "Long-run Growth," 20. The label 'new' refers to industries generally associated with the Second Industrial Revolution.

more than twice as large as the accumulation component observed for the traditional industries. This reflects the modernization process in British manufacturing that was, as discussed above, most pronounced in the new industries. The contribution of capital deepening to American productivity in the new and traditional industries was substantially smaller, and the gap between the US and Great Britain arguably demonstrates the technological convergence that took place during this period. As technological change still progressed at a considerably higher pace in the US compared to Britain, however, it is clear that technological convergence was far from complete by 1930.[94]

Institutional constraints

As illustrated above, only those British firms that were part of the new industries that in the US had benefited most from the advent of electrification, mass-production, and the introduction of professional management chose to risk the expenditure required for the successful adoption of these modern, capital-intensive, production techniques.[95] Nonetheless, even in those British industries that chose to invest, the transformation to mass production lacked the vigor and dynamism that characterized the US and which was also apparent in Germany during the early twentieth century.[96] Below, I will highlight the role of institutions in the relatively hesitant adoption of capital-intensive production techniques in the more dynamic British industries.

For the motor vehicle industry, Lewchuk shows that British producers were reluctant to install new technologies as they wanted to limit their vulnerability to slowdowns, something which they could afford as a result of the protection imparted by tariffs and an oligopoly dominated by Morris Motors.[97] Other sectors adopted similar anti-competitive behavior, which was sanctioned by government policy. As Britain was rapidly losing its dominant place in the world market, the interwar economy witnessed a major shift in supply-side policy as the British government became more and more willing to intervene in the market economy. Crafts notes that, "among the innovations of this period were the beginnings of industrial policy in the 1920s, the general tariff of 1932, the encouragement of cartels and the imposition of controls on foreign

94. One must bear in mind though that the technological change listed in table 4.3 is a geometric average and represents the vertical shift of the frontier both at the capital-intensity level of 1907 and 1930. In the British new industries, technological change measured at interwar capital intensity levels was more than double that of the period prior to the First World War (2.3 versus 1.0 percent). This large shift illustrates once more the biased nature of technological change during this period, at least for the modern industries.

95. For a detailed discussion of the impact of electrification on productivity change see, Jong, *Catching Up Twice: the Nature of Dutch Industrial Growth During the Twentieth Century in a Comparative Perspective*, 154–61.

96. Veenstra and Woltjer, "The Yanks of Europe?"

97. Lewchuk, *American Technology and the British Vehicle Industry*.

investment in the 1930s."[98] The latter arrangements allowed firms to adopt conduct which avoided competition. Consequently, modernization and rationalization where no longer a prerequisite to survival. Instead, firms opted for a defensive strategy and engaged in collusive behavior.[99]

Another institutional constraint to modernization in the interwar years was the rapid expansion of the craft unions. During the war, workers had been encouraged to join unions as a matter of public policy. Once freed from wartime restraints, the British unions became increasingly assertive.[100] "Menaced by the advent of skill-displacing technologies, which threatened to challenge their dominance of the workplace, craft unions used their power on the shop floor to enforce traditional practices in the workplace in terms of the numbers employed, training, routines and piece rates. Such attempts were more successful in industries like shipbuilding and cotton spinning, where skilled craft labor could not be easily replaced and was relatively better organized than its employers."[101] The craft unions had not yet established a solid foothold in the new industries, such as pharmaceuticals, automobiles and electrical equipment, which consequently led managers to face less opposition during the process of modernization. Admittedly, the high rate of unemployment witnessed during the interwar period eroded the bargaining power of unions, which may have enhanced the ability of firms to push for organizational and technical change. The rise of cartelization diluted the incentive for doing so, however.[102]

The imposition of an elaborate tariff system sheltered British manufacturing from foreign competition, which further weakened the need to increase efficiency and push for organizational change. Where the tariffs and the encouragement of cartels may have mattered most, however, was in retarding the transfer of resources to new uses.[103] As, in the 1920s and 1930s, demand weakened for the goods from the industries in which Britain had invested most in the nineteenth century (i.e. coal, iron and steel, textiles and shipbuilding) the market economy should have begun to reallocate resources out of these uses. Instead, the British manufacturing sector was slow to move into the new industries. Several scholars have interpreted this slow transformation in terms of the handicap of an early start.[104] The experience and skills accumulated by coal min-

98. Crafts, "Long-run Growth," 18.
99. Bowden and Higgins, "British Industry in the Interwar Years," 379.
100. Eichengreen, "The British Economy Between the Wars," 320–1.
101. Magee, "Manufacturing and Technological Change," 93.
102. Eichengreen, "The British Economy Between the Wars," 341.
103. ibid., 338.
104. Svennilson, *Growth and Stagnation in the European Economy*; M. Frankel, "Obsolescence and Technological Change in a Maturing Economy," *American Economic Review* 45 (1955): 296–319; C. Kindleberger, "Obsolescence and Technical Change," *Bulleting of the Oxford University Institute of Economics and Statistics* 23 (1961): 281–297; E. Ames and N. Rosenberg, "Changing Technological Leadership and Industrial Growth," *Economic Journal* 73 (1963): 13–31.

ers and shipyard workers, for instance, were ill-suited to the more technologically sophisticated new industries. In addition, the old and new industries were often located in different places.[105] Buttressed by tariffs and cartels, British manufacturing continued to specialize in the old staples. This only stalled the difficult transition process. Productivity growth in the new industries was in fact faster than in other branches of manufacturing, a fact that suggests that Britain's relative overcommitment to the old staples reduced the manufacturing sector's overall rate of expansion and slowed down the modernization process.[106]

The slower growth of demand in Britain did have additional consequences for the rate of technological change as well, by affecting the rate at which machinery was replaced. As noted by Salter, gross investment was the vehicle of technological change – since technological change was largely embodied in new capital equipment – and the rate of investment largely determined how rapidly new techniques were brought into general use and were effective in raising productivity.[107] Slower demand therefore accounted for the frequently reported reluctance of British manufacturers to discard their old machinery at the same rate as their American competitors.[108] Salter showed that the best-practice plants in Britain reported similar capital intensities, applied identical production methods and had comparable levels of productivity compared to the best plants in the US. "The difference," he claimed, "lies in a much higher proportion of plants employing outmoded methods in the United Kingdom."[109] The disparity in the 'standards of obsolescence' was one of the driving forces behind the Anglo-American productivity gap during the first half of the twentieth century. Nonetheless, the dichotomy of production techniques in British manufacturing, as observed by Salter, emphasizes once more that British producers did not eschew modern, capital-intensive, production techniques, but that its capital stock was simply slow to adjust to the rapid technological evolution of the time.

Another, often cited, factor that inhibited investment was the prevalence of family firms in the British manufacturing sector.[110] It is argued that the relatively small British firms failed to capture economies of scale and scope inherent in new technologies. Opportunities which German and American manufactures seized both domestically and internationally.[111] Yet, by international standards British firms were not exceptionally small. When comparing employment data, we see that the average man-

105. Eichengreen, "The British Economy Between the Wars," 327–8.
106. See table 4.3, or Magee, "Manufacturing and Technological Change," 78.
107. Salter, *Productivity and Technical Change*, 64–5.
108. Magee, "Manufacturing and Technological Change," 82.
109. Salter, *Productivity and Technical Change*, 72–3.
110. A. Chandler, *Scale and Scope: The Dynamics of Industrial Capitalism* (Harvard: Belknap Press of Harvard University Press, 1990).
111. T. Nicholas, "Enterprise and Management," chap. 9 in Floud and Johnson, *The Cambridge Economic History of Modern Britain*, 2:243.

ufacturing establishment in Britain employed 64 people, compared to 67 in the US, 14 in Germany and 26 in France. As emphasized by Magee, "The largest British chemical firm in 1903, United Alkali, employed over a thousand more workers than BASF, Germany's biggest manufacturer of the time. It was only in the heavy industries, such as iron and steel, that British plants were comparatively small."[112]

More generally, Elbaum and Lazonick claim that the institutional legacy associated with atomistic, nineteenth century economic organization impeded the adoption of modern technological and organizational innovations. "Entrenched institutional structures – in industrial relations, enterprise and market organization, education, finance, international trade, and state-enterprise relations – constrained the transformation of Britain's productive system."[113] Nonetheless, these 'institutional rigidities', did not prevent British firms in the new industries from adopting modern mechanized production techniques, investing in continuous-flow manufacturing and introducing modern techniques of managerial control. The supply-side policies of the interwar period merely served to slow the modernization process and retarded the transfer of resources to these new industries.

The lock-in hypothesis of British technical choice also presumes a static relation between the cost of capital and labor. During the interwar years, these relative factor costs were far from stable, however. Broadberry shows that the average weekly hours fell by approximately 13 percent at a time when the real wage for a 'normal' working week was rising steadily.[114] The raise in hourly labor costs was not matched by an immediate increase in the hourly labor productivity, making effective labor relatively more expensive in Britain.[115] At the same time, technical progress itself exerted continuous downward pressure on the cost of capital goods.[116] The cheapening of capital goods relative to wages gave further impetus to the modernization and rationalization movement in British manufacturing, particularly in those industries where capital could be easily substituted for skilled labor.

British growth after the Second World War

Crafts shows that, during the period 1950 to 1973, "Britain experienced its fastest-ever economic growth but at the same time relative economic decline proceeded at a rapid rate vis-a-vis its European peer group such that by the end of the period Britain had been overtaken by [...] nine other [countries] in terms of labour productivity."[117]

112. Magee, "Manufacturing and Technological Change," 79–80.
113. B. Elbaum and W. Lazonick, *The Decline of the British Economy* (Oxford: Clarendon Press, 1986), 2.
114. S. Broadberry, "Aggregate Supply in Interwar Britain," *Economic Journal* 96 (1986): 469.
115. Eichengreen, "The British Economy Between the Wars," 324.
116. Salter, *Productivity and Technical Change*, 35–6.
117. Crafts, "British Relative Economic Decline Revisited," 22.

Following the Second World War, the interwar policies that reduced competitive pressures on British business change proved hard to displace and turned out to have long-lasting effects on output growth and productivity convergence. Even though a sizable portion of British manufacturing had successfully taken the first step in the Basu and Weil model and had created considerable potential for growth during the 1920s and 1930s, the implementation of the crucial second stage, 'learning-by-doing', proved to be more problematic. The process of learning-by-doing was, in the case of Britain, decelerated by an inflexible labor market and strong unions, as well as the cartelization and collusive practices previously described. The industries that had implemented capital-intensive production techniques felt reduced pressure to optimize their efficiency levels, as tariffs and cartels created a "cozy environment sheltered from the chill winds of competition."[118] Furthermore, British commitment to education and human capital formation lagged behind its major international rivals.[119] Traditionally, Britain provided less basic education to its general labor force and directed educational reform toward clerical skills. This left the country relatively poorly placed to take full advantage of the new technologies introduced in the early twentieth century. "This was a legacy that was to cause twentieth-century difficulties," as emphasized by Harley, "it was an efficient response to Britain's position as the first industrialized country, perhaps, but a restraint on future growth."[120] As a result, Britain was less successful than other European nations in exploiting the opportunities for catch-up growth, gradually losing ground against her European rivals.[121] Nonetheless, as illustrated by Crafts and Mills, labor-productivity growth between 1951 and 1973 was considerably faster in the UK than in the US, resulting in the gradual decline of the Anglo-American productivity gap.[122] The post-war productivity convergence supports the premise of a two-tiered process of catch-up growth that, for Great Britain, had its origins in the interwar era.

4.5 Conclusion

As noted by Tomlinson, the economic history literature on early-twentieth century British manufacturing has taken a rather despondent, or 'declinist', view. "Every industry or even company's failure to match performance in another country has been

118. Eichengreen, "The British Economy Between the Wars," 338.
119. See chapter 5 for a discussion.
120. K. Harley, "Trade, 1870–1939: From Globalization to Fragmentation," chap. 7 in Floud and Johnson, *The Cambridge Economic History of Modern Britain*, 2:175.
121. C. Bean and N. Crafts, "British Economic Growth Since 1945: Relative Economic Decline and Renaissance?," chap. 6 in *Economic Growth in Europe Since 1945*, ed. N. Crafts and G. Toniolo (Cambridge: Cambridge University Press, 1996), 133.
122. Crafts and Mills, "Europe's Golden Age," 421.

commonly treated not as part of the rough and tumble life of global capitalism, or even as the result of contingent error and miscalculation, but rather as a symptom of profound economic, but also political, social and cultural malaise."[123] In part, Broadberry's thesis that the divergence of Anglo-American labor productivity reflected the persistence of distinct industrial technologies in Europe and the United States, follows this tradition. He argues that, in the face of different endowments and demand patterns British producers continued to pursue a crafts-based production system, inevitably losing both productivity and technological leadership to the American system of mass-production.

This chapter presents a rather more positive view of interwar British manufacturing, as I reassess the productivity dynamics on the basis of Basu and Weil's model of appropriate technology, which predicts convergence in light of capital deepening. I show that a substantial part of British manufacturing, particularly the 'new' industries of the Second Industrial Revolution, was drawn toward the American mechanized production techniques and exhibited substantial growth potential. These new industries – i.e. chemicals, transportation equipment, electrical engineering and printing – exhibited strong rates of technological progress that was decidedly biased. Because of this bias in technological progress, labor productivity grew fastest for capital-intensive techniques during the first half of the twentieth century, which prompted British manufactures to rapidly increase their rate of capital deepening. These findings are confirmed by examples of the introduction of modern mechanized production techniques, investment in continuous-flow manufacturing and the adoption of new techniques of managerial control. By confirming that parts of British manufacturing was successfully adapting to the rapidly changing environment, I can reject the premise that the entire manufacturing sector was locked-in a separate technology path, as argued by Broadberry.

However, in spite of these clear examples of British mechanization, the modernization process was severely hampered by government intervention in an attempt to correct market failures, the dominance of craft unions and pre-existing production practices. Supply-side policies of the interwar period slowed the modernization process and retarded the transfer of resources to new industries. The reluctance to adopt modern production techniques is particularly apparent for the traditional industries. My figures indicate that the old staples such as building materials, clothing, and textiles showed little signs of convergence in terms of capital intensity levels. Consequently, in contrast to Broadberry, in my estimates I do not observe a single development path for all manufacturing industries, but instead I find large heterogeneity in the modern-

123. J. Tomlinson, "Thrice Denied: 'Declinism' as a Recurrent Theme in British History of the Long Twentieth Century," *Twentieth Century British History* 20 (2009): 228.

ization process within British manufacturing.

Even though British manufacturing converged on the US in terms of capital-intensity levels, the Anglo-American productivity gap failed to narrow and even widened during the interwar period. I show that, particularly for the modern industries, the capital-deepening process was accompanied by a large productivity growth potential which, however, did not materialize as low levels of technical efficiency stood in the way of convergence. Following Basu and Weil's appropriate-technology model, I interpret the decrease of relative efficiency as a feature of modernization inextricably linked to the first phase of catch-up growth, i.e. creating potential. Only after an economy has adjusted to the new situation and has exhausted the full potential of the new technology the labor-productivity gap to the frontier can be narrowed. In the case of postwar Britain this process of learning-by-doing was decelerated by an inflexible labor market and strong unions, as well as cartelization and widespread collusive practices. This 'institutional legacy' caused Britain to be less successful than other European nations in exploiting the opportunities for catch-up growth following the Second World War, thus causing her to gradually lose ground against her major European rivals. Nonetheless, the UK experienced significantly stronger trend growth than the US between 1951 and 1973 and the two economies converged in terms of labor-productivity levels.

4.A Note on American data

The basic source of output, employment and capital data for US industries is the *Census of Manufactures*. Data on total employment, value added and total horsepower employed is available in the quinquennial censuses between 1899 and 1919 and the biennial censuses of 1923 to 1929 and 1939.[124] In this appendix I will define the basic variables, discuss the comparability of the figures between different census years and clarify the industry classification.

Basic sources

Nominal value added is derived directly from the census figures as the net of the ex-factory value of products (the selling value at the factory or plants) minus the cost of materials, purchased fuel and electric energy and contract work. No attempt was made to adjust for inventory revaluations or fully account for maintenance work and repairs, but evidence presented by Fabricant suggests that these adjustments would only marginally affect gross value added for the years in my sample.[125] I calculated deflators at the industry level on the basis of the Fabricant indices of physical output and nominal output series.[126] Subsequently, I incorporated the modifications and extensions to the indices of production proposed by Kendrick.[127] Lastly, I reclassified these deflators to fit the 1945 Standard Industry Classification (SIC), which constitutes the basis for both the Kendrick series and my own.[128] Throughout, nominal value added was converted to constant prices (with a 1929 base) by applying the price deflators at the two-digit SIC level.

I define employment as the sum of wage earners, salaried officers and employees.[129] I exclude all proprietors and firm members as I wish to limit my analysis to manufacturing personnel whose activity directly contributes to the value added reported in the census. In censuses prior to 1935, manufactures were instructed to report all personnel employed in both production activities and in auxiliary activities such as maintenance, shipping, warehousing, etc. at the same location. My employment figures thus invariably include a number of employees engaged in these kinds

124. United States Department of Commerce: Bureau of the Census, “Manufactures”; United States Department of Commerce: Bureau of the Census, “Manufactures”; United States Department of Commerce: Bureau of the Census, “Manufactures: General Report”; United States Department of Commerce: Bureau of the Census, “Manufactures: Statistics by Subjects.”
125. Fabricant, *The Output of Manufacturing Industries*, 340–50.
126. ibid., 123–321, 605–39; 1939 physical output was derived from United States Department of Commerce: Bureau of the Census, “Indexes of Production,” in *Census of Manufactures 1947*, 1.
127. Kendrick, *Productivity trends in the United States*, 416–21, 467–75.
128. For the computation of the aggregate price indices I maintained the Marshall-Edgeworth formula with 1909, 1919 and 1929 as base-years.
129. The category ’salaried officers and employees’ includes all superintendents, managers and clerical workers.

of non-manufacturing activities. This distinction is complicated further by the 1939 schedule that asked employers to report separate figures for their manufacturing and non-manufacturing personnel, based either on- or off-site. Although it is difficult to establish to what extent this change in definition affects the comparability of the employment figures between the censuses, Fabricant concludes that "the implicit census definition of factory employment has given rise to no serious ambiguities in the data."[130] For 1939 I included all non-manufacturing personnel in my employment totals while still excluding proprietors and firm members, which is compatible with the definition applied by Kendrick for this year.[131]

The census employment figures were converted to total hours worked on the basis of industry-specific average annual hours of work obtained from various sources. For the inter-war period I relied on data by Inklaar et al., who provide detailed estimates of average hours of work for wage earners.[132] I extended their dataset to include the census years prior to World War I. The censuses of 1909 and 1914 provide industry specific data on prevailing hours of labor per week; no data is available for the years 1899 and 1904, I used the 1909 average hours instead.[133] I normalized the industry-specific weekly hours over the total manufacturing figures provided by Jones, using census wage earners as weights.[134] Lastly, I converted the prewar estimates to annual average hours worked, based on the 1900 estimate of American vacation and holidays by Huberman and Minns.[135]

Capital intensity is defined as the sum of the horsepower capacity of prime movers and the horsepower rating of motors driven by purchased electric energy, divided by my measure of employment. This definition coincides with the census measure of primary power, which also excludes the power of electric motors run by current generated in the same establishment to prevent duplication. The census years 1921 and 1931 to 1937 were entirely excluded from my sample as data on power equipment was either not collected or incomplete for these years. Although it is likely that rates of capacity utilization have changed during my period of study, partly as a result of the shift from the use of prime movers toward electric motors, I was unable to adjust for these.

130. S. Fabricant, *Employment in Manufacturing, 1899–1939* (New York: National Bureau Economic Analysis, 1942), 173.
131. Kendrick, *Productivity trends in the United States*, 434.
132. Inklaar, Jong, and Gouma, "Did Technology Shocks Drive the Great Depression?," 852–4. These figures relate exclusively to wage earners, however this group comprises the bulk of my employment measure, and any deviations in hours worked between wage earners and salaried officers and employees are bound to be small compared to the annual fluctuations observed during this period.
133. United States Department of Commerce: Bureau of the Census, "Manufactures," 316–9; United States Department of Commerce: Bureau of the Census, *Abstract of the Census of Manufactures 1914* (Washington D.C.: United States Government Printing Office, 1917), 482–9.
134. Jones, "New Estimates of Hours of Work per Week," 375.
135. Huberman and Minns, "Days and Hours of Work in Old and New Worlds," 546.

Scope and comparability

During the 1899–1939 period the scope of the activities covered by the census has changed somewhat. Prior to 1919, the American industrial census exempted all establishments with an annual production valued at less than $500; for the years since 1919 this limit was raised to $5,000. In the 1921 census report this resulted in a 21.6 percent reduction in the number of establishments covered. However, the comparability of the figures since 1919 were not appreciably affected as, according to the United States Bureau of the Census, "99.4 percent of the total wage earners and 99.7 of the total value of products reported at that census [1919, red.] were contributed by the establishments reporting products to the value of $5,000 or more."[136] In addition, from 1904 onwards, the Census of Manufactures was confined to establishments conducting work under the *factory system*, thus excluding neighborhood industries and hand trades. For 1899 I relied on reclassified figures provided in the 1909 census. The adjusted figures omit all non-factory establishments for 1899 and are thus fully comparable to the statistics for subsequent census years.[137]

Over the course of my period of study several major industries, engaged in activities no longer considered as manufacturing, were excluded from the census.[138] I followed this convention and withdrew these industries from my sample. Over the various censuses numerous changes were made to the classification of industries and products, inevitably resulting in discontinuities and breaks in the series. Fabricant discusses the continuity of the census value added and employment data over the period 1899 to 1939 at length.[139] Overall, predominantly smaller industries were affected by the changes across the various census years, thus limiting the overall impact on the coherence of the data set. Where necessary, I have combined related industries into aggregate groupings to ensure continuity.[140]

Standard industrial classification

In my analysis I rely on the industrial classification laid out in the 1947 Census of Manufactures.[141] The census classification was derived from the 1945 *Standard Indus-*

136. United States Department of Commerce: Bureau of the Census, "Manufactures: Statistics by Subjects," 2.
137. United States Department of Commerce: Bureau of the Census, "Manufactures," 507–17; both the 1899 and 1904 data were taken from the 1909 census report.
138. Important industries that were dropped are motion picture production, manufactured gas, automobile repairing, and railroad repair shops. See e.g. Kendrick, *Productivity trends in the United States*, 404.
139. Fabricant, *The Output of Manufacturing Industries*, 605–39; Fabricant, *Employment in Manufacturing*, 179–230.
140. E.g. Cigarettes (211) and Cigars (212) were combined into an aggregate industry group as well as Flat Glass (321) and Pressed and Blown Glassware (322).
141. United States Department of Commerce: Bureau of the Census, "Statistics by Industry," 862–914.

trial Classification (SIC), which was the first attempt to standardize the collection and reporting of data across different agencies while maintaining consistency over a longer time-frame.[142] The industrial classification groups establishments primarily engaged in the same line or similar lines of economic activity which, in the case of manufacturing, is generally defined in terms of the products made (demand side) or the processes of manufacture used (supply side).[143] The SIC scheme places primary emphasis on the latter, whereas the original, prewar, census classifications relies heavily on the former.[144] The supply-side grouping of businesses – i.e. the categorization according to the way in which inputs are transformed into outputs, mainly depending on the technology used – fits neatly into my productivity study. Although the SIC has undergone several revisions (the latest in 1987), I explicitly chose to use the 1945 vintage as the introduction of new products and production techniques over time make the more recent classifications less applicable to the period preceding the Second World War.

Following the standard industrial classification, the manufacturing division comprises approximately 450 industries in 1939, which are included in 127 industry groups and 20 major groups.[145] These major groups are commonly referred to as two-digit industries and are broken down into three-digit industries (i.e. industry groups), which in turn are separated into four-digit industries.[146] I restrict my analysis to the three-digit level, moderately modified to ensure continuity, leaving me with 105 observations for each of the 10 census years. I generally estimate a frontier at the two-digit level, implicitly assuming that industries share a production function at this level of aggregation. As previously noted, the SIC groups industries according to a similarity in their inputs, outputs or use of production techniques, giving credence to the assumption of a joint production function. For a number of two-digit industries this assumption was violated, in which case I estimate two or more frontiers for that respective group.[147]

142. The differences between the 1947 census and the 1945 SIC are minor; for a detailed discussion see ibid., 931–3.
143. Kendrick, *Productivity trends in the United States*, 405–6.
144. Although in many respects the SIC resembles the prewar census classifications, there have been a number of important changes that highlight the shift from a demand-side to a supply-side oriented classification. Notably in metals, the prewar censuses grouped establishments according to whether they produced ferrous or nonferrous products. The 1945 SIC reclassified these industry groups according to whether the production process was mainly associated with primary production (e.g. refining, smelting, rolling, etc.) or the production of finished metal products (e.g. nails, wire, hardware, etc.), regardless of the type of metal from which the end-product consisted.
145. United States Department of Commerce: Bureau of the Census, “Statistics by Industry,” 915.
146. Carter et al., *Historical Statistics of the United States*, 4:4.
147. The most notable example is *chemicals and allied products* (28) for which five separate technology frontiers were estimated. See table 4.4 for further details.

4.B Note on British data

The primary British data is taken from the First and Fourth *Census of Production*.[148] In this appendix I will provide an in-depth discussion of the basic variables and methods of construction behind this data set. I explore the amendments required for changes in geographical coverage and discuss the exclusion of small firms. In addition, I analyze the comparability of the British and American data and review the steps required to make them analogous.

Basic sources

As was the case for the US, British output, labor and capital data is derived from the official production censuses. I selected the years 1907 and 1930, as both these surveys contain detailed information on gross output, intermediate inputs, employment and installed horsepower. Even though the terminology in the British and American censuses differ slightly, the concepts of value added, employment and horsepower capacity are equivalent for both countries. Gross output is again defined as the ex-factory value of products, whereas intermediate input represents the cost of materials, fuel and contract work. Value added, or net output, is the net of gross output and intermediate input and constitutes the sum of wages, salaries, rent, royalties, rates and taxes, depreciation of plant and machinery, advertisement and selling expenses and all other similar charges as well as profits.

As a first step in the construction of my data set, I reclassified the British industrial classification to fit the 1945 US Standard Industrial Classification (see appendix 4.A). As was the case for the American data, I restrict the classification to the three-digit level. The level of detail in the British classification necessitated a number of modifications to the level of aggregation in order to maintain comparability and continuity over time.[149] The resulting data set consists of 64 observations for both 1907 and 1930 and cover the British factory trades in their entirety.

Subsequently, I converted British output to nominal dollar values on the basis of the price conversion factors introduced in chapters 2 and 3. In both these industry-of-origin studies the industry level conversion factors were calculated on the basis of producer prices, using the procedures first set out by Paige and Bombach and clearly exposited in the work of van Ark.[150] Note that the interwar PPPs rely on price data

148. Board of Trade, *Final Report on the First Census of Production of the UK*; Board of Trade, *Final Report on the Fourth Census of Production of the UK*.

149. Particularly the British engineering trades lacked the detail specified in the US SIC. In this case I opted for the lowest feasible aggregation level based on the detail provided in the census.

150. Paige and Bombach, *A Comparison of National Output and Productivity*; Ark, *International Comparisons of Output and Productivity*.

taken the Fifth Census of Production, which refers to the year 1935.[151] I extrapolated the interwar conversion factors to a 1930 base using price deflators taken from the work of Feinstein.[152] The nominal dollar values were then converted to constant prices (with a 1929 base) by applying the American price deflators, discussed in appendix 4.A above. Both the Anglo-American PPPs and the American price deflators were implemented at the two-digit SIC level.

For Britain I define employment as the sum of operatives (wage earners) and administrative, technical and clerical staff. In line with the definition used for the US, I include only those personnel whose activity directly contributes to the firm's production (thus excluding owners and firm members). I converted the 1907 employment figures to annual hours of work on the basis of Matthews et al. estimate of the average number of weeks worked per year as well as weekly hours of work listed in the British Labour Statistics.[153] For the interwar period I again rely on Matthews et al., but base my estimate of the average length of the working week on a study by the International Labour Office.[154]

For the British capital-intensity data I utilize the American formula of adding up horsepower of prime movers and of electric motors using purchased electricity. The 1930 census directly reports both the power available from prime movers and the horsepower of electric motors driven by purchased electricity. Unfortunately, no data is available for the horsepower capacity of electric motors in 1907 and I rely on figures of electricity purchased to estimate the horsepower of electric motors.[155] The prewar census does provide detailed figures on the total capacity of (non-electric) prime movers, however.

Scope and comparability

The 1930 census deals exclusively with industrial production in England, Wales and Scotland, whereas the 1907 Census of Production relates to United Kingdom as a whole. Fortunately, the 1907 census does provide separate figures for England and

151. Board of Trade, *Final Report on the Fifth Census of Production*.
152. Feinstein, *Statistical Tables of National Income, Expenditure and Output of the UK*, 61–9.
153. Note that the figures for the average length of the working week are industry specific and refer to the year 1906. Great Britain Department of Employment and Productivity, *British Labour Statistics: Historical Abstract*, 95; Matthews, Feinstein, and Odling-Smee, *British Economic Growth, 1856–1973*, 566.
154. ibid.; International Labour Office, *Year Book of Labour Statistics 1939*, 82–3.
155. Although my estimate of electric motors driven by purchased energy is fairly rough, its possible impact on the British capital intensity figures is limited as electric motors were still fairly uncommon at this time. Comparable figures for the US and Germany reveal that, prior to the First World War, less than 20 percent of the installed horsepower consisted of electric motors, while only a fraction of these were run by purchased electricity.

Wales, Scotland and Ireland.[156] To make the prewar census directly comparable to the interwar census, I excluded Ireland from the 1907 sample and rely exclusively on the production figures for Great Britain. This adjustment does not materially affect the productivity estimates, however, as only a fraction of industrial production in the United Kingdom took place in Ireland at this time.[157]

Comparability between both census years is affected by the exemption of small firms from the interwar schedule. At the 1930 census, firms employing ten persons or less were exempted from making detailed returns. Full returns were required from all businesses, irrespective of their size, at the 1907 census. Although the extent of the bias is difficult to determine, evidence presented by Rostas suggests that small plants and firms generally have a lower productivity than their larger counterparts.[158] The exclusion of these firms from the 1930 schedule thus results in an overestimate of efficiency and productivity in comparison to the prewar numbers.[159] In all, the proportion of the people working in British manufacturing employed by smaller firms is estimated in the 1930 census at approximately 10 percent.[160] On the basis of this proportion, Fremdling et al. reckon that an upward bias of approximately 2 percent is introduced in the British interwar productivity statistics.[161] As noted in appendix 4.A, prior to the First World War, the US census exempted only those establishments with an annual production valued at $500 or less. As the average output per person engaged in manufacturing amounted to $2,560 in 1909, the scope of the American census is thus nearly as wide as the 1907 British census.[162]

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156. In some cases the Board of Trade chose to aggregate the production figures to prevent the disclosure of particulars relating to specific firms. The latter measure is taken primarily for small Irish firms that have no, or only a few, direct competitors within the confines of the country. Consequently, although my data for 1907 does, invariably, include some residual production figures for Ireland, the overall impact is limited on account of the small size of the firms in question.
157. The production in Ireland focused mainly on the textiles and food sectors and, overall, accounted for just 3.2 percent of net output and 4.2 percent of employment in the manufacturing sector of the United Kingdom. Board of Trade, *Final Report on the First Census of Production of the UK*, 18–9.
158. L. Rostas, *Productivity, Prices and Distribution in Selected British Industries* (Cambridge: Cambridge University Press, 1948), 28–32.
159. Rostas, *Comparative Productivity in British and American Industry*, 25.
160. Board of Trade, *Final Report on the Fourth Census of Production of the UK*, V:9–11,
161. Fremdling, Jong, and Timmer, "British and German Manufacturing Productivity Compared," 372–3.
162. United States Department of Commerce: Bureau of the Census, "Manufactures."

4.C Distance functions

In this chapter I emphasize the role of technological change as a driver behind the wave of modernization that marked the interwar period and stress the importance of efficiency behind the British productivity dynamics of the 1920s and 1930s, particularly in relation to the US. Studies on technological change in the Anglo-American convergence debate have so far primarily been based on traditional growth accounting exercises. These studies assume that an economy is operating on its production function, and consequently, treat total-factor productivity (TFP) analogous to technological change. Such an interpretation is prone to serious limitations, however, as it usually requires several restrictive assumptions such as allocative and technical efficiency, factor-neutral technological change and constant returns-to-scale.[163] By adopting a data envelopment analysis (DEA), which applies non-parametric linear programming techniques, I can decompose TFP into two mutually exclusive and exhaustive components: (1) changes in technological efficiency and (2) shifts in technology over time. In addition, as the DEA does not require the imposition of a particular functional form on the production frontier, it allows for any type of technological change, be it biased or factor-neutral.[164]

In this appendix I will summarize the basic framework behind the DEA, based primarily on the work of Färe, Grosskopf and Lovell.[165] They illustrate that a distance function can be used to determine the Farrell efficiency indices of a production set for any number of inputs or outputs. In appendix 4.D I will show that, on the basis of the efficiency scores, a (global) production frontier can be constructed, which in turn allows me to determine the change in technology over time.[166] In this basic example I assume that all inputs and output quantities are non-negative and that, for each time period $t = 1, \dots, T$, the production technology S^t models the transformation of N inputs, $x^t \in \mathbb{R}_+^N$, into M outputs, $y^t \in \mathbb{R}_+^M$

$$S^t = \left\{ (x^t, y^t) : x^t \text{ can produce } y^t \right\} \tag{4.2}$$

163. The number of restrictive assumptions within a growth accounting framework is primarily dependent on the choice of production function. A translog production function, for instance, is much more flexible than a Cobb Douglas specification and does not assume rigid premises such as perfect substitution between production factors or perfect competition. Nonetheless, the vast majority of growth accounting studies in economic history still rely on the restrictive Cobb Douglass production function.
164. The main advantage of the DEA technique is its flexibility and adaptability. A DEA allows for multiple inputs and outputs, does not require input- or output-prices and does not require behavioral assumptions such as cost minimization or profit maximization.
165. Färe, Grosskopf, and Lovell, *Production Frontiers*.
166. Färe et al., "Productivity Growth, Technical Progress, and Efficiency Change," 68–9.

The input distance function $D_i^t(x^t, y^t)$ at time t is defined as

$$D_i^t(x^t, y^t) = \min\left\{\theta : (\theta x^t, y^t) \in S^t\right\} \tag{4.3}$$

For the constant returns-to-scale case and a technology set S^t, the input distance function for production $(x^{j,t}, y^{j,t})$ can be specified as

$$\min_{\theta,\lambda^1,\ldots,\lambda^k} \quad \theta \quad \text{subject to}$$

$$\begin{aligned} y^{jt} &\leq \sum_k \lambda^k y^{kt} \\ \theta x^{jt} &\geq \sum_k \lambda^k x^{kt} \\ \lambda^k &\geq 0 \; \forall \; k. \end{aligned} \tag{4.4}$$

The solution to the linear program for the intensity vector λ^* and efficiency index θ^* can be interpreted as follows. There is a (hypothetical) composite producer formed as a non-negative linear combination of all k observations using the components of λ^*. This composite producer consumes no more than θ^* times observation j's inputs, while still producing j's output. The composite producer thus represents a fully efficient producer who is located on the global production frontier at j's output level, while θ^* represents the ratio between both the inputs of the composite producer and x_j^t respectively. Note that if $(x^t, y^t) \in S^t$, the Farrell efficiency index θ will take on a value between 0 and 1, where a value of 1 implies full efficiency.

The observations for which the input distance function returns a θ equal to 1 together determine the position and shape of the production frontier. The frontier is formed by tightly enveloping the fully efficient observations, or 'best practice' activities, with linear segments; as illustrated in figure 4.1 in the main text. The frontier is thus a subset of all feasible techniques that attain the highest labor productivity for the capital intensity levels they correspond to.[167]

Although, so far I base my results on the assumption of constant returns-to-scale, Färe et al. show that the flexible nature of the DEA allows me to relax this assumption.[168] The constraint $\lambda^k \geq 0$ implies constant returns-to-scale. By controlling the intensity factor with additional constraints, i.e. $\sum_k \lambda^k \leq 1$ or $\sum_k \lambda^k = 1$, I can impose non-increasing and variable returns-to-scale respectively. The imposition of these additional constraints does come at a cost of greatly increased data requirements however. A sensitivity check on the basis of variable returns-to-scale, which can be found

167. Timmer and Los, "Localized Innovation and Productivity Growth in Asia," 52.
168. Färe, Grosskopf, and Lovell, *Production Frontiers*, 32–7.

in appendix 4.E, demonstrates that the constant returns assumption does not significantly alter the findings presented throughout this chapter; I therefore feel confident using it.

4.D Technological change

So far I have limited the discussion of the bias in technological progress to a graphical representation of the change for a small sample of manufacturing industries. In this section I will illustrate the graphical representation of the change in technology over time and subsequently discuss the observed bias in technological change for the remaining industries in my sample. This will allow me to determine whether, during the interwar years, technological progress was biased toward capital-intensive production techniques. Overall, I confirm the existence of a substantial bias in technological change. For a select number of manufacturing industries, however, I find evidence that suggests technological change was factor-neutral. For the latter industries, the pull toward American-style production techniques appears to be absent, whereas for industries that experienced strongly biased technological change British firms were drawn toward more capital-intensive ways of production.

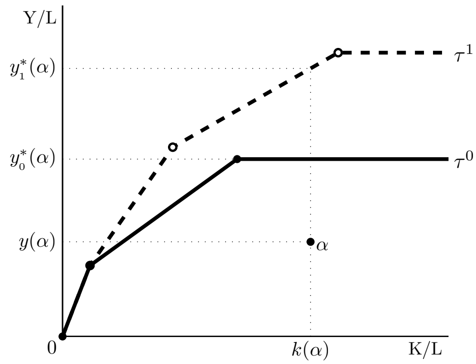
Figure 4.6 presents a graphical representation of technological change. In this figure I return to the basic constant returns-to-scale case for two inputs (K and L) and one output (Y). In the left pane, observed production α and two frontier-technology sets are represented in $\langle k, y \rangle$ space, where y is labor productivity (Y/L) and k is capital intensity (K/L). The observation α is interior to the boundary of technology at time 0 and 1, and is thus technically inefficient. To find the fully efficient input mix for this observation – i.e. the intersect with the frontier – I utilize the input-based distance function introduced in equation (4.4). The distance function seeks the greatest proportional decrease in inputs, given the target output. In this example, the distance function yields θ^* which, for α, represents the ratio between the minimum amount of labor required and actual labor employed while still producing at least $Y(\alpha)$.[169] The maximum feasible productivity, at the technology level of period 0, is thus represented by

$$y_0^*(\alpha) = \frac{Y(\alpha)}{\theta_0^* L(\alpha)} = y(\alpha)/\theta_0^* \qquad (4.5)$$

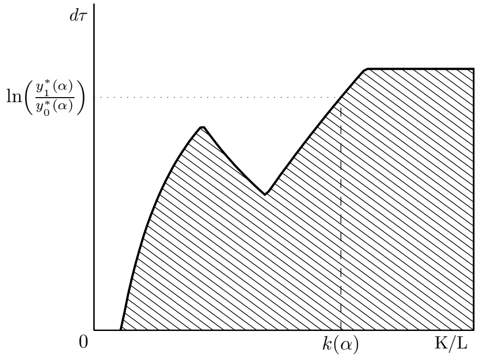
Technological change over time for α is represented in the left panel of figure 4.6 by the vertical shift of the frontier; i.e. the ratio between the maximum feasible productivity at time 1 and 0, or alternatively, the relative efficiency of α in period 0 divided by α's

169. Note that θ^* represents this ratio for all inputs. The optimal capital intensity level for α is thus identical to its actual level, as $k(\alpha) = \theta^* K(\alpha)/\theta^* L(\alpha) = K(\alpha)/L(\alpha)$.

Figure 4.6: Frontiers and technological change



(**a**) technology frontier



(**b**) technological change

efficiency with respect to the frontier in period 1.

$$\text{technological change} = \frac{y_1^*(\alpha)}{y_0^*(\alpha)} = \frac{y(\alpha)/\theta_1^*}{y(\alpha)/\theta_0^*} = \frac{\theta_0^*}{\theta_1^*} \tag{4.6}$$

The right panel of figure 4.6 depicts the log change of technology between the two periods (i.e. $\ln\left(\frac{y_1^*(\alpha)}{y_0^*(\alpha)}\right)$ or similarly $\Delta\ln(y)$) for both $k(\alpha)$ and any other feasible capital-intensity level that falls within the technology set. The diagram thus depicts the relation between capital intensity and potential labor productivity change. As noted in section 4.3, the bias in technological progress can be gauged by the skewness of the diagram.

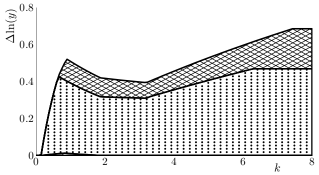
Figure 4.7 holds the graphs of technological change for all twenty-seven industry-groups in my sample; table 4.4 provides a brief description for each industry.[170] For the majority of manufacturing industries technological change exhibited a strong bias toward capital-intensive production techniques. For a select number of manufacturing industries, however, I observe no apparent capital-intensity bias in the rate of technological change, as discussed in the main text.

170. Note that for the SIC labels I followed the following convention. The first two digits refer to the major industry group, the third digit specifies the exact industries part of that group. A 't' is used to join all industries between the digits prior to and following the marker, 'n' joins only those digits actually listed (thus excluding those in-between), and the 'x' is used as a wild-card, referring to all three-digit industries that are not mentioned elsewhere; i.e. 20 refers to the entire two-digit SIC group 'Food and kindred products', 227 refers to the 'Carpets and rugs' industries which is part of the two-digit group 22, 'Textiles', whereas 22x refers to all remaining industries in this group. 357t9 concerns the industries 357, 358 and 359, while 371n25 refers solely to 371, 372 and 375.

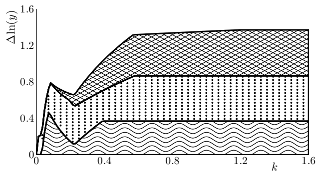
Table 4.4: Characteristics of technology frontiers

sic	*description*	*sic*	*description*
20	Food and kindred products	29	Petroleum and coal products
21	Tobacco manufactures	30	Rubber products
22x	Textile mill products (misc.)	31	Leather and leather products
227	Carpets and rugs	32	Stone, clay, and glass products
23	Apparel and related products	33	Primary metal industries
24t5	Lumber and wood products	34	Fabricated metal products
261	Pulp, paper, and paperboard	35x	Machinery (except electrical)
26x	Paper and allied products (misc.)	357t9	Office and household machinery
27	Printing and publishing	36	Electrical machinery
281t2	Industrial chemicals	371n25	Motor vehicles, -cycles and aircraft
283	Drugs and medicines	37x	Transportation equipment (misc.)
284	Soap and related products	38	Instruments and related products
28x	Chemicals (misc.)	39	Miscellaneous manufactures
287t8	Fertilizers and oils		

Figure 4.7: Technological change



(**4.7.1**) ind. 20



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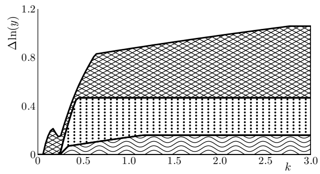

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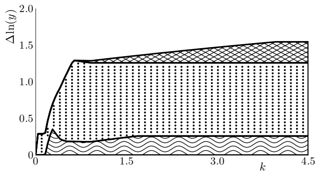

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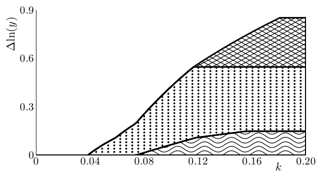
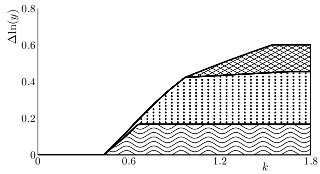


(**4.7.5**) ind. 23



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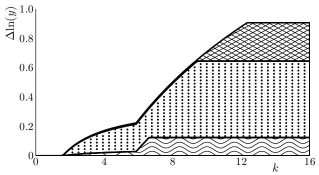
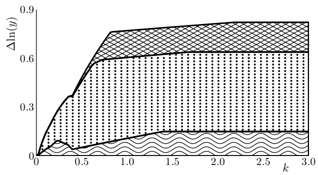


(**4.7.7**) ind. 261



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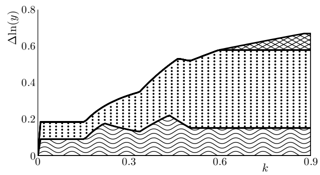
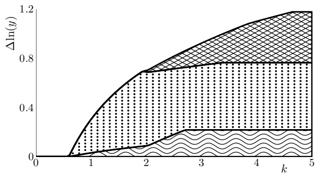
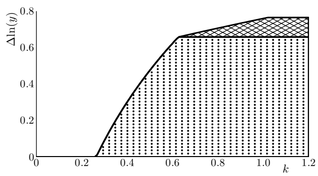


(**4.7.9**) ind. 27



(**4.7.10**) ind. 281t2



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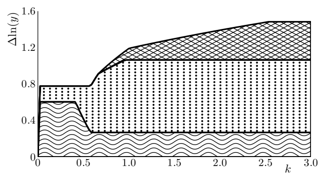

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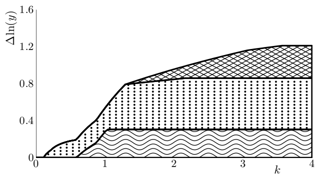

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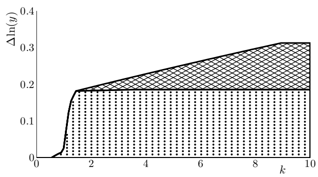
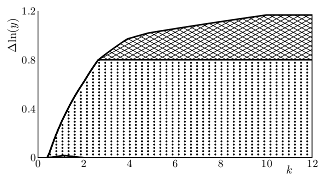
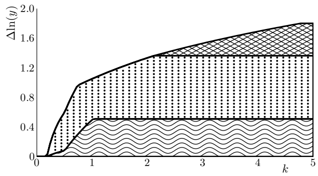


(**4.7.14**) ind. 287t8



(**4.7.15**) ind. 29

Figure 4.7: Technological change (continued)



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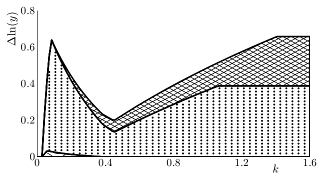

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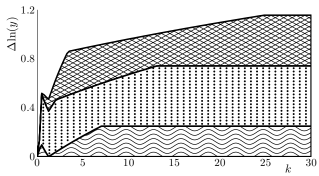

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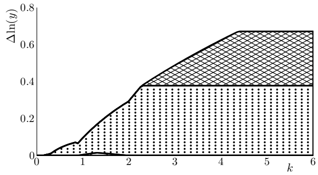

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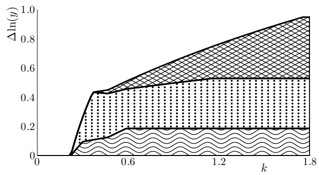

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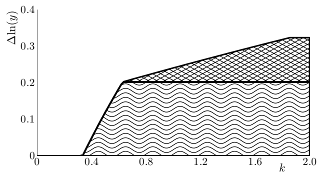

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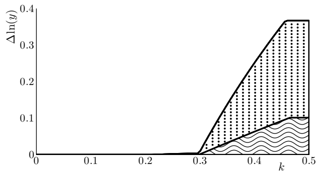

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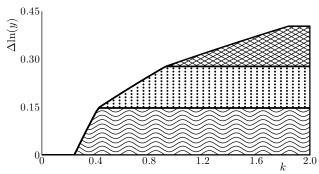

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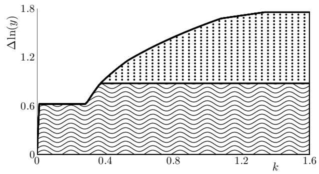

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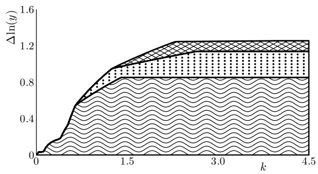

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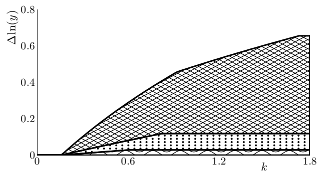

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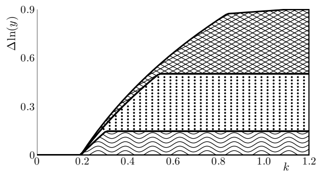
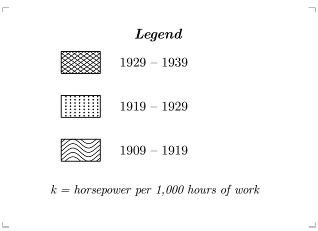


(4.7.27) ind. 39



4.E Robustness checks

In this section I consider several robustness checks that address three of the more vital assumptions that could lead my estimates to under- or overstate the effects of technological progress and efficiency change on productivity growth. First, I investigate the impact of alternative returns-to-scale models. Second, I consider the effects of estimating the production frontiers at the 3-digit SIC level. Lastly, I re-run my analysis on the basis of total employment instead of hours worked. I conclude that the constraints imposed throughout this chapter do not appear to bias the main results.

Returns to scale

Throughout this chapter I have based my decomposition results on the assumption of constant returns-to-scale (CRS). This assumption is only appropriate, however, when all industries are operating at an optimal scale, which can be frustrated by imperfect competition, constraints on finance, etc. In this case, the efficiency measures based on the CRS model are biased downwards by the occurrence of scale efficiencies. A variable returns-to-scale (VRS) specification excludes these scale efficiencies and envelopes the production points more tightly. Consequently, the latter yields technical efficiency scores greater than or equal to those obtained from the CRS model.

As noted in appendix 4.C, the flexibility of the DEA permits me to relax the CRS constraint and assume VRS instead. The VRS specification does increase the requirements on the data set, however. A graphical representation of the frontier illustrates this problem. The two-input, one-output case would require the addition of a third dimension, as labor productivity is now not only dependent on the level of capital intensity but on the scale of production as well. Given the added dimension and the increased surface area of the frontier, a greater portion of the observations will form part of the (VRS) frontier and will thus be classified as fully efficient. The problem of unobserved production – either of represented countries in the past or of otherwise unrepresented peers – is thus confounded. What would now be interpreted as frontier movements could in fact be assimilation of knowledge associated with unobserved appropriate techniques. The VRS specification increases the degrees of freedom of the model, which could present identification problems for those frontiers for which I only have a limited number of observations. Nonetheless, if both models yield comparable results, we may conclude that the CRS assumption is appropriate for the interwar Euro-American productivity comparison. If, however, large discrepancies are observed in the decomposition results, this may signal that either my restrictive returns-to-scale assumption is not valid or that the VRS model suffers from insufficient observations.

The decomposition results for total manufacturing, based on both the CRS and VRS

Table 4.5: Robustness checks, total manufacturing, US and GB

	annual average growth rate, in ln%			
	total	*accumu-lation*	*tech. change*	*effi-ciency*
CRS	**3.1**	**0.7**	**2.2**	**0.2**
VRS	3.1	0.6	2.4	0.1
3DIGIT	3.1	1.0	1.9	0.2
EMP	2.5	0.5	1.7	0.3

(a) US Manufacturing, 1909–1929

	annual average growth rate, in ln%			
	total	*accumu-lation*	*tech. change*	*effi-ciency*
CRS	**3.0**	**0.8**	**2.0**	**0.3**
VRS	3.0	0.9	2.0	0.1
3DIGIT	3.0	1.0	1.8	0.2
EMP	1.7	0.4	1.2	0.0

(b) US Manufacturing, 1909–1939

	annual average growth rate, in ln%			
	total	*accumu-lation*	*tech. change*	*effi-ciency*
CRS	**1.9**	**1.7**	**1.4**	**-1.2**
VRS	1.9	1.9	1.6	-1.6
3DIGIT	1.9	2.5	0.9	-1.5
EMP	1.2	1.5	1.1	-1.3

(c) GB Manufacturing, 1907–1930

method, are provided in table 4.5. The table lists the aggregate results for the US and Great Britain separately. For the American decomposition, both the sub-period 1909–1929 as well as the entire 1909–1939 period are given. Note that, while the annual log growth of labor productivity remains unaltered by the choice of a returns-to-scale model, the components of the Kumar and Russell decomposition can still be affected.

Overall, the differences between both models, at the highest level of aggregation, appear to be limited. Typically, the VRS model reports a mild increase of the accumulation and technology components, at the expense of efficiency. Yet, the general conclusions remain unchanged. American labor productivity is driven by rapid technological change and, to a lesser degree, capital accumulation. American efficiency change, for both periods, is small and can primarily be attributed to a gainful shift in the employment structure. For British manufacturing, the greatest contribution to labor-productivity growth results from capital deepening. Technological change in Britain, for the VRS model, still falls short of the progress experienced in the US, but is substantive nonetheless. Under the VRS specification, efficiency decreases considerably over time for Britain. As noted above, this may be caused by scale (in)efficiencies or alternatively an insufficient number of observations. In either case, the CRS assumption does not fundamentally alter my findings, I thus feel confident using it.

Frontier selection

In my analysis I have so far estimated a frontier for 27 industry groups. In the estimation of the frontiers I pool all the three-digit observations that belong to the same two-digit industry group, thus assuming that these observations share a production function at this level of aggregation. As an implicit check I observe whether the three-digit industries in a common group will, at any point in time, be part of, or closely approach, the frontier. Only a small number of industries failed to pass this simple test, in which case I estimated an additional frontier for these observations. Only the chemicals sector, whose industries proved particularly hard to group, required more than two distinct frontiers. Table 4.4 in appendix 4.D provides an overview of the two-digit frontiers in this study.

Alternatively, I can estimate a separate frontier for each of the 105 three-digit industries in my sample. However, the increase in the number of frontiers does lower the average number of observations per frontier, which could present similar data problems as those previously discussed in the returns-to-scale section. Table 4.5 lists the decomposition results for total manufacturing based on this alternative frontier selection (3DIGIT), which can be directly compared to the basic, two-digit CRS decomposition. These two decompositions present a similar picture. For both countries, the technology component is lower than is the case for the standard CRS model, while the accumulation component is elevated. Particularly for Great Britain, the effect of capital deepening is more pronounced, accompanied by a more substantial decrease in efficiency. Nonetheless, the results based on the extended selection of frontiers are in broad agreement with the findings presented in the main text. As the impact of the alternative frontier selection is very similar for both Britain and the US and I am particularly interested in the difference in the development of capital deepening, efficiency and technological change *between* both countries, I conclude that the grouping of industries into two-digit frontiers is a valid approach for this study.

Employment

As a final robustness check I turn to the definition of employment. Throughout this chapter I relied on total hours worked as a measure of labor input, primarily because this measure captures the substantial drop in the average length of the working week that occurred during the interwar years. In contrast, previous productivity studies have often relied on basic employment measures – looking exclusively at the total number of active wage earners and employees in an industry – which thus makes comparison between these studies and my own analysis more difficult.[171] To facilitate this comparison and to determine whether a decomposition based on employment numbers (EMP) provides comparable results to my basic, hours-based decomposition (CRS), I have re-run the analysis on a per-worker basis and presented the results in table 4.5.

The reduction in the average length of the working week, which was evident in both countries, clearly shows in table 4.5. The total labor-productivity change for EMP is distinctly lower than my productivity measure based on hours worked (CRS), particularly when I include the 1930s in the analysis. The decomposition results reflect this reduction, but otherwise remain unaffected. For the US, technological change is still the driving force behind the change in productivity, while growth in Britain originates primarily from capital accumulation. In addition, for Great Britain I also observe a clear positive impact of technology accompanied by a worsening of efficiency. Nonetheless, I feel the EMP specification severely undervalues the impact of technological progress, particularly for the 1930s, which Field has shown to be one of the most progressive decades of the twentieth century.[172] I therefore prefer the hours worked measure of employment.

171. Broadberry, *The Productivity Race*.
172. Field, "The Most Technologically Progressive Decade of the Century."

4.F Disaggregate results

Table 4.6: Decomposition of labor-productivity growth, United States (1909–1929)

			annual average growth rate (ln%)				
sic	*description*	*total*	*accumu-lation*	*tech. change*	*effi-ciency*	*dK/L*	*indus-tries*
20	Food and kindred products	2.4	0.8	1.7	-0.2	2.3	8
21	Tobacco manufactures	6.4	4.3	2.4	-0.3	6.3	2
22	Textile mill products	2.3	0.1	2.3	-0.1	2.4	8
23	Apparel and related products	2.4	0.8	1.4	0.3	2.0	6
24t5	Lumber and woods products	1.7	0.2	2.0	-0.6	2.0	4
26	Paper and allied products	3.4	1.1	2.2	0.1	2.6	5
27	Printing and publishing	3.8	1.0	2.5	0.3	2.1	5
28	Chemicals and allied products	4.0	0.7	2.7	0.6	3.7	8
29	Petroleum and coal products	5.3	0.9	3.2	1.2	6.3	4
30	Rubber products	7.9	0.8	5.7	1.4	4.6	3
31	Leather and leather products	2.2	0.8	1.7	-0.4	3.4	8
32	Stone, clay, and glass products	3.3	0.4	2.4	0.5	4.6	7
33	Primary metal industries	2.3	0.4	1.7	0.2	2.3	4
34	Fabricated metal products	2.7	0.3	2.3	0.0	3.8	8
35	Machinery (except electrical)	2.2	0.1	1.6	0.5	4.2	7
36	Electrical machinery	2.2	0.2	1.2	0.8	2.4	2
37	Transportation equipment	8.2	2.0	5.6	0.6	5.1	5
38	Instruments and related products	2.0	0.1	0.2	1.7	3.6	6
39	Miscellaneous manufactures	2.4	0.7	1.7	0.0	3.2	6
D	MANUFACTURING	3.1	0.7	2.2	0.2	3.1	106

Table 4.7: Decomposition of labor-productivity growth, Great Britain (1907–1930)

		annual average growth rate (ln%)					
sic	*description*	*total*	*accumu-lation*	*tech. change*	*effi-ciency*	*dK/L*	*indus-tries*
20	Food and kindred products	1.3	2.3	0.8	-1.9	3.2	8
21	Tobacco manufactures	3.9	2.7	2.7	-1.5	5.2	1
22	Textile mill products	2.8	0.3	1.9	0.6	3.1	6
23	Apparel and related products	2.3	4.1	0.7	-2.5	6.1	3
24t5	Lumber and woods products	-0.9	2.0	0.4	-3.3	3.6	3
26	Paper and allied products	1.9	2.4	0.5	-1.1	3.7	3
27	Printing and publishing	2.7	3.7	1.5	-2.4	5.1	2
28	Chemicals and allied products	1.0	2.0	2.1	-3.1	4.5	6
29	Petroleum and coal products	1.2	1.2	2.4	-2.4	3.8	3
30	Rubber products	5.2	1.7	3.8	-0.2	5.3	1
31	Leather and leather products	1.0	1.4	1.8	-2.2	5.5	4
32	Stone, clay, and glass products	2.1	1.0	1.5	-0.4	3.5	4
33	Primary metal industries	0.1	0.5	1.3	-1.7	3.5	3
34	Fabricated metal products	1.9	2.4	1.3	-1.7	6.3	3
35	Machinery (except electrical)	0.0	0.6	0.4	-1.0	5.0	1
36	Electrical machinery	1.8	0.4	0.5	1.0	3.4	1
37	Transportation equipment	3.6	3.6	3.0	-3.0	4.8	4
38	Instruments and related products	2.6	2.9	0.1	-0.3	5.8	2
39	Miscellaneous manufactures	2.8	4.0	0.6	-1.8	6.5	6
D	MANUFACTURING	1.9	1.7	1.4	-1.2	3.8	64

Chapter 5

The American Human Capital Revolution

Labor Quality in the United States, 1900–1950

5.1 Introduction

In *The Race between Education and Technology*, Claudia Goldin and Lawrence Katz provide an in-depth and persuasive account of the twentieth century as the 'human capital century'.[1] They reserve a special role for the United States, which showed exceptional leadership in investing in the skill of its workforce. They characterize the exceptional American attitude toward human capital as follows:

> "For most Americans in the early twentieth century access to schooling, at least through high school, was largely unlimited by personal station and residence. Education was publicly provided and was free of direct charge, except at the highest levels. [. . .] Americans had a strong tradition of educating their youth at public charge and the expansion of education beyond the common school and elementary grades continued a commitment rooted in basic democratic and egalitarian principles."[2]

The American approach to schooling in the early twentieth century stood in stark contrast to the European education system, which was still largely reserved for the relatively rich. The differences in school attendance rates between the United Kingdom

1. Goldin and Katz, *The Race Between Education and Technology*, 11.
2. ibid., 12.

and the United States exemplify the fundamental differences in the commitment to publicly provide education. Goldin shows that by 1930, compared to Britain, the US was already three to four decades ahead in post-elementary education, a lead which remained large well into the second half of the twentieth century.[3] The advances in schooling during the early twentieth century transformed the American workforce. The formal, school based education provided general training which prepared the American youth for a wide array of potential tasks and occupations and allowed them to adequately respond to the considerable technological change that marked this period.[4] America's approach to schooling was thus one of the driving forces behind its technological dynamism and paved the way for rapid economic growth.[5] The hesitance of European nations to follow the American example inevitably led to the US forging ahead of its main industrial rivals, as we have seen in the previous chapters.

Given its importance, surprisingly little is known about the exact contribution of the advances in educational attainment and the resulting changes in *labor quality* on America's productivity potential for the early twentieth century. As I will show in section 5.2, several attempts were made to quantify the role that education played in labor-quality growth. Nearly all of these studies retain a highly macro-economic focus, however, exclusively studying the effects of labor-quality change at the total economy level.[6] By confining their study to the aggregate workforce, the previous analyses overlook the marked differences in levels and growth rates of labor quality for individual sectors and appear to underestimate the effects of shifts of (skilled) workers between the major economic branches. Goldin and Katz show that, in 1940, certain manufacturing industries disproportionately hired more educated workers and that these industries "produced newer products and used more advanced technologies."[7] This complementarity between skill and technology highlights the role of labor quality in explaining the patterns of technological progress at the sectoral level.[8]

The aim of this study is to produce new, sectoral measures of labor-quality change for the 1900–1950 period. In order to fully assess the impact of the substantial investments in schooling on the American economy in general and sectoral labor input in particular, I turn to an approach developed by Dale Jorgenson and Zvi Griliches.[9] The

3. Goldin, "The Human-Capital Century and American Leadership," 267.
4. Goldin and Katz, *The Race Between Education and Technology*, 29.
5. ibid., 12.
6. The seminal contribution to the measurement of American labor input and quality for the early twentieth century is the work by Denison, see Denison, *The Sources of Economic Growth in the United States*; E. Denison, *Accounting for United States Economic Growth, 1929–1969* (Washington D.C.: The Brookings Institution, 1974); E. Denison, *Trends in American Economic Growth, 1929–1982* (Washington D.C.: Brookings Institution Press, 1985).
7. Goldin and Katz, *The Race Between Education and Technology*, 108.
8. ibid., 89–91.
9. Griliches, "The Sources of Measured Productivity Growth," 340; Jorgenson and Griliches, "The Explanation of Productivity Change."

key innovations in their work was to adjust the traditional measure of labor input – i.e. total hours of work or employment – for improvements in quality. The main principle behind the labor quality adjustment is the distinction among several different types of labor inputs characterized by one or more quantifiable factors that affect the productivity potential of the worker (e.g. educational attainment, experience, etc.). By then assigning weights to these categories, they measure the change in the productivity 'potential' of the workforce. The rationale for this procedure is that differences in average earnings between the labor categories can be thought of as reflecting differences in their marginal productivity. When this new measure of labor input is used in a growth accounting framework – instead of a basic measure of the number of employees or hours worked – output growth as a result of better educated and trained workers are ascribed to input growth, rather than productivity or technology growth.[10] Previous studies have shown that this quality adjusted measure can account for a substantial part of the residual or Total Factor Productivity (TFP) growth within traditional growth accounting studies.[11] For the 1929–1957 period, Edward Denison attributes 1.08 percentage points (or approximately one-third) of annual productivity growth to changes in educational attainment, experience and the gender composition of the American workforce. Overall, the labor quality adjustment allows for a purer measure of both labor input as well as technical change within a growth accounting framework. The results presented in this chapter will allow for such a quality adjustment for the American economy during the first half of the twentieth century.

I utilize the microdata from the Integrated Public Use Microdata Series (IPUMS).[12] This source contains detailed employment records from the decennial population censuses for nearly 10 million individuals between 1900 and 1950, allowing me to construct my labor input measure. Unfortunately, however, the 1900–1930 population censuses did not inquire into either the educational attainment of the general population or the compensation of workers and employees. To overcome these data issues, I follow a two-tiered approach to the labor quality estimation. First, I estimate educational attainment at the micro level for the pre-1940 census samples on the basis of the 1940 returns. Second, I construct an employment matrix for the entire period that groups workers according to their (predicted) educational attainment, gender, experience and industry. These groups are then aggregated to the sector and total economy

10. Jorgenson, Ho, and Stiroh, "A Retrospective Look at the U.S. Productivity Growth Resurgence."

11. Denison, *The Sources of Economic Growth in the United States*; Griliches, "The Sources of Measured Productivity Growth"; Denison and Poullier, *Why Growth Rates Differ*; Jorgenson, Ho, and Stiroh, "A Retrospective Look at the U.S. Productivity Growth Resurgence"; R. Gordon, "Revisiting U.S. Productivity Growth Over the Past Century With A View of the Future," *National Bureau of Economic Research Working Paper* 15834 (2010): 1–30.

12. S. Ruggles et al., *Integrated Public Use Microdata Series*, 5.0 (Minneapolis: University of Minnesota, 2010).

level using 1940 labor-compensation weights. The resulting indices are the first ever attempt to provide a detailed breakdown of labor-quality change for all the major sectors of the US economy for the period prior to the Second World War.

This chapter is structured as follows. First, I discuss the previous attempts to quantify the contribution of the advances in educational attainment for the early twentieth century. Next, in section 5.3, I provide a brief overview of the basic methods behind the estimation of educational attainment and labor quality and discuss the primary sources used for this study. The main results are discussed in section 5.4, followed by a discussion of their relevance to the ongoing human-capital debate in section 5.5. In the last section I conclude.

5.2 Previous labor quality estimates

One of the earliest attempts to quantify the role of labor-quality change was undertaken by John Kendrick.[13] Incidentally, his study was also the only one to date to measure American labor quality at the total economy as well as the sectoral level for the early twentieth century. However, as I will illustrate below, the measure employed by Kendrick only partially captures the change in the skill of the labor force and seriously underestimates the growth of labor quality at the sectoral level. Later estimates by, notably, Denison are able to capture the full extent of education's contribution to labor-quality growth as well as assess the effects of changes in the female participation rates and overall experience of the labor force. Overall, Denison finds a considerably more rapid skill increase of the total US workforce during the 1909–1957 period than suggested by Kendrick. Unfortunately, Denison's study is restricted to the total economy level and does not provide independent figures for the main economic sectors. This study presents new measures of labor-quality change broadly in line with the figures presented by Denison, but complemented by detailed sectoral estimates. These estimate not only provide a new understanding of skill change for the individual economic sectors, but will also allow me to fully capture the effects of the reallocation of labor between these sectors. The latter turns out to have had a significant impact on overall labor-quality growth between 1900 and 1950.

Kendrick assessed the effect of skill changes on the composition of the labor force between 1869 and 1957. Instead of measuring changes in education attainment, gender and experience directly, however, he measured the changes in the occupational structure. He adjusted labor input by weighting the man-hours of work in separate occupations and industries by their average hourly earnings for a given base year. Kendrick's measure of labor quality thus captures two effects: (1) the relative shifts

13. Kendrick, *Productivity trends in the United States*, 31–4.

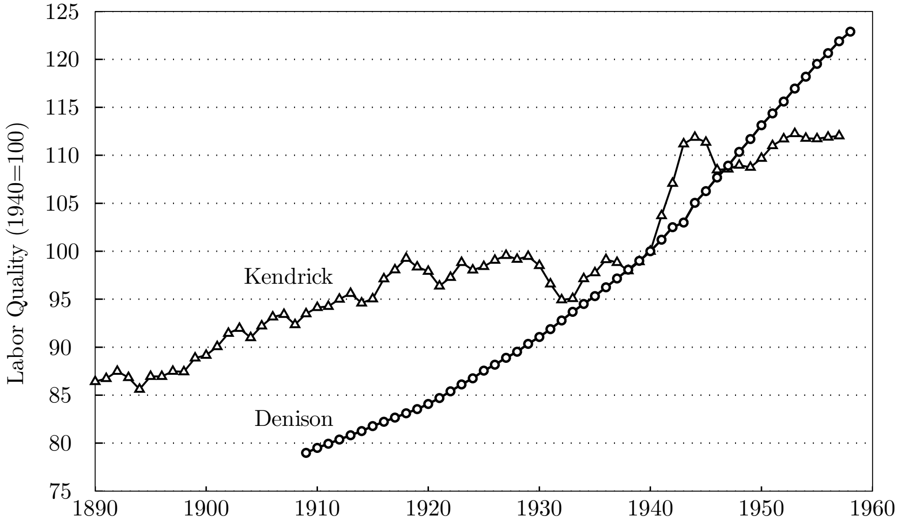
of workers between occupations, and (2) the relocation of employment between industries. The first effect, the shift of workers from low-paying positions (e.g. laborers) to better-paying jobs (e.g. operatives or clerical staff), reflects a change in the potential output per worker. The higher earnings (measured in terms of base-period compensation) imply a rise in the marginal productivity of that worker and thus a rise in the quality of the labor force – in line with the Jorgenson approach.[14] Likewise, the shift of workers to better-paying industries also show up as an increase in labor quality.

Kendrick assumes under (1) that labor quality will only change over time if a worker transfers from one occupation to another or if an individual joins (or leaves) the labor force in an occupation that is better (worse) paid than the national average. He surmises that "the inherent average physical and mental capacity of the person employed in each occupation is constant over time."[15] The rapid increase in educational attainment, as illustrated in the previous section, casts serious doubt on this assumption, however. The average years of schooling for cohorts born between 1880 and 1950 nearly doubled, increasing from approximately 8 to 14 years.[16] Part of this increase in skill translated in a shift of employees between occupations and industries, but part also translated in a rise of the labor quality *within* occupations. For instance, the likelihood for a blue collar worker born around 1885 to have attended high school was substantially greater than it was for its counterpart born only 10 years prior, around 1875.[17] The high-school education gave the blue-collar worker basic knowledge of chemistry, electricity and algebra, allowed him to read manuals and blueprints and made it much easier for him to effectively converse with managers and other professionals, raising his marginal productivity in the process.[18] In addition to undervaluing the impact of the rapid increases in education attainment during the late nineteenth and early twentieth century, Kendrick's method ignores other demographic changes as well. Changes in the average age, or experience of the workforce and shifts in the gender composition are generally considered to be determining factors in the quality of labor, as I will illustrate below.

Figure 5.1 plots Kendrick's implicit labor quality figures. The index is derived by subtracting the change in man-hours for the national economy from the change in Kendrick's estimate of labor input.[19] Kendrick predicts a constant increase in labor quality of roughly 0.5 percent before 1920, little to no growth between 1920 and 1940 and a very rapid increase during the war years. This development clashes

14. R. Raimon and V. Stoikov, "The Quality of the Labor Force," *Industrial and Labor Relations Review* 20 (1967): 391–413.
15. Kendrick, *Productivity trends in the United States*, 33.
16. Goldin and Katz, *The Race Between Education and Technology*, 20.
17. ibid., 170.
18. ibid., 113.
19. Kendrick, *Productivity trends in the United States*, 328–9.

Figure 5.1: Labor quality estimates, Kendrick vs. Denison (1890–1960)



Source: J. Kendrick, *Productivity Trends in the United States* (Princeton: National Bureau Economic Research, 1961), 328–9; E. Denison, *The Sources of Economic Growth in the United States and the Alternatives Before Us* (New York: Committee for Economic Development, 1962), 85.

with Goldin and Katz' observation that the average years of schooling continuously increased throughout the first three quarters of the twentieth century.[20] Particularly the stagnation of labor quality during the 1920s and 1930s is not reflected in the development of human capital and would suggest a structural divide between the educational attainment of the workforce and the population as a whole. This divide could result from sudden shifts in labor-force participation rates, either following from the inflow of lesser skilled or the outflow of more skilled workers. There is no evidence for such a bias, however. At the height of the Great Depression we can actually observe a movement in the opposite direction. During the depression years, unskilled workers suffered the highest rates of unemployment as they were being replaced by skilled workers willing to perform unskilled labor.[21] This would have actually raised labor quality during the 1930s not lowered it, as suggested by Kendrick.

At the sectoral level the downward bias in Kendrick's figures is even more apparent. The limited scope for shifts between occupations and industries restricts the method adopted by Kendrick to fully capture changes in labor quality at this lower level of aggregation. Consequently, Kendrick records very limited growth between

20. Goldin and Katz, *The Race Between Education and Technology*, 20.
21. R. Jensen, "The Causes and Cures of Unemployment in the Great Depression," *Journal of Interdisciplinary History* 19 (1989): 567–8.

1899 and 1948 for most of the non-service sectors. He cites growth rates of 1.3 percent in mining and 7.9 percent in manufacturing respectively, while failing to report estimates for agriculture, construction and trade altogether.[22] These estimates are well below the economy's overall growth of 20.3 percent during the same period and suggest only a minor role for labor-quality change in industrial output growth – quite contrary to the claims by Goldin and Katz.[23] Notwithstanding the downward bias in Kendrick's methodology and limited sectoral coverage, his figures for labor quality in the service sector show much greater dynamism. For communications and public utilities he estimates an overall growth of labor quality between 1899 and 1948 of 14.5 percent; 29.9 percent in finance and (personal and professional) services; but a decline of 4.3 percent in transportation.[24] The considerable rise in labor quality in the personal and professional services represents the shift of primarily women from jobs as service workers (e.g. housekeepers) to clerical occupations (e.g. stenographers, typists, and secretaries). The clerical work required far greater skill and education than that demanded of service workers, confirming that the transition captured by Kendrick's figures indeed represents a rise in labor quality for this sector.[25]

Following Kendrick's work, several authors contributed to the debate by quantifying the role of education in economic growth by either measuring the change in the number of years of schooling for the labor force in connection with the earnings differentials directly, or estimating the amount of capital invested in education in conjunction with a rate of return on that capital.[26] The previously mentioned study by Denison, in particular, overturned the conventional wisdom regarding the impact of labor-quality change on output growth. On the basis of a framework similar but not identical to the one later used by Griliches and Jorgenson, he adjusted total economy man-hours for the increased levels of education, rise in experience and changes in the age-sex composition of the labor force. On the basis of these adjustments Denison estimates an overall change in labor quality of 0.67 percent per annum between 1909 and 1929 and 1.08 percent between 1929 and 1957.[27]

Figure 5.1 illustrates that the labor quality series by Denison grows considerably faster than the Kendrick series. The rapidly improving educational attainment of the

22. Kendrick, *Productivity trends in the United States*, 365–6, 397–8.
23. ibid., 328–9.
24. ibid., 541–2, 581–2, 610.
25. Goldin and Katz, *The Race Between Education and Technology*, 172–5.
26. Denison, *The Sources of Economic Growth in the United States*; Griliches, "The Sources of Measured Productivity Growth"; T. Schultz, "Investment in Human Capital," *American Economic Review* 51 (1961): 1–17; G. Psacharopoulos, "Measuring the Marginal Contribution of Education to Economic Growth," *Economic Development and Cultural Change* 20 (1972): 641–658; Denison, *Trends in American Economic Growth*.
27. Denison, *The Sources of Economic Growth in the United States*, 265; R. Gordon, "Interpreting the One Big Wave in US Long-Term Productivity Growth," *National Bureau of Economic Research Working Paper* 7752 (2000): 13–7.

workforce contributed most to labor-quality growth – Denison estimated education to have added about 0.56 percentage points of growth to labor input between 1909–1929 and 0.93 during the period 1929–1957.[28] Changes in the composition of the workforce were responsible for the remaining growth of labor quality. Denison argues that the downward bias on labor quality resulting from the sharp rise in the labor-force participation rates for women – which generally earned less than their 'male equivalents', implying a lower marginal productivity – was entirely offset by a rise in the average experience of the workforce. Particularly women themselves started to work for longer and thus became much more experienced which "materially improved the average quality of female labor."[29] In addition, Denison shows that the relaxation of institutional barriers to the hiring and promotion of women in the better paying jobs contributed to the improvement of labor quality during this period.

Denison's approach aroused considerable criticism, however, centered primarily on his adjustments for shorter hours of work and increased education.[30] As noted by Robert Gordon, Denison's adjustments for education diverges from the standard Jorgenson approach in two important respects: (1) he arbitrarily assumed that ability rather than educational attainment alone explained 40 percent of the observed differences in earnings across educational attainment categories, and (2) he raised his education estimate by assuming that an increase in the *length* of the school year had the same effect on production as a similar increase in the *number* of school years attended by an individual.[31] Although, the second assumption may be relevant to the period under study – as the average number of days of school attended per year rose rapidly during the first half of the twentieth century – overall, Denison's two assumptions appear to cancel each other out. Consequently, in this study I chose to drop Denison's adjustment for ability, disregard the change in the length of the school year and focus solely on the change in the average years of schooling instead. The figures for the contribution of education to American labor-quality growth, presented below, could thus be regarded as a conservative estimate.

As previously noted, Denison does not provide sectoral measures of labor-quality growth. Kendrick's figures demonstrate, however, that labor quality can develop quite distinctly between sectors. In addition, improvements in the utilization of the workforce – in the form of labor relocating from low-productive to high-productive industries – can have a notable impact on overall labor quality. Denison, well aware of the latter issue, made adjustments for the 1929–1957 period to account for the shift of la-

28. Denison, *The Sources of Economic Growth in the United States*, 73.
29. ibid., 80.
30. G. Fromm, "The Sources of Economic Growth in the United States and the Alternatives Before Us: Book Review," *American Statistical Association Journal* 58 (1963): 1168–1171.
31. Gordon, "Interpreting the One Big Wave in US Long-Term Productivity Growth," 15.

bor from the agricultural sector to industry and services.[32] On the basis of this rough adjustment, he found a very small contribution to overall labor-quality growth of less than 0.02 percentage points annually. As I will show below, this greatly underestimates the actual impact of the relocation of labor. Mainly the expansion of the service sector and 'high-tech' manufacturing industries, not explicitly covered by Denison's adjustment, contributed to labor-quality growth.

For the post-war US economy the standard labor-quality series are based on the seminal work by Jorgenson and Griliches.[33] These authors combined hours worked for various labor types into a constant quality index of labor input, using labor compensation per hour as weights.[34] Initially, the authors looked solely at the male workforce broken down by the number of school years completed.[35] Later work by Jorgenson et al. extended this to include female workers and distinguish labor service categories classified by age, sex, occupation, industry and educational attainment.[36] They find that labor quality rose quickly between 1948 and 1970 followed by a slowdown during the 1970s and 1980s. This reflected the influx of younger workers and a tapering off of the growth rate of educational attainment during the latter period.[37]

5.3 Methodology and data

As noted in section 5.1, I follow the approach advocated by Jorgenson et al. and measure labor quality as changes in the composition of the workforce.[38] To construct an index of labor input for each individual sector, I assume that labor input for sector i (L_i) can be expressed as a translog function of its individual components.[39] I form sectoral indices of labor input from data on employment by industry, cross-classified by sex, age and education (N_{il}). Below I use the subscript l to represent all labor characteristics listed in table 5.1, except for industry. Changes in the employment for each component are weighted by average shares in sectoral labor compensation ($\overline{v}_{il}$).

32. Denison, *The Sources of Economic Growth in the United States*, 209–10.
33. Jorgenson and Griliches, "The Explanation of Productivity Change."
34. D. Jorgenson, "Accounting for Growth in the Information Age," chap. 10 in *Handbook of Economic Growth*, ed. P. Aghion and S. Durlauf, vol. 1A (Amsterdam: Elsevier, 2005), 782.
35. Jorgenson and Griliches, "The Explanation of Productivity Change," 269.
36. D. Jorgenson and B. Fraumeni, "The Accumulation of Human and Nonhuman Capital, 1948–1984," chap. 5 in *The Measurement of Saving, Investment, and Wealth*, ed. R. Lipsey and H. Tice, vol. 52, Studies in Income and Wealth (Chicago: University of Chicago Press, 1989), 227–282; D. Jorgenson, F. Gollop, and B. Fraumeni, *Productivity and US Economic Growth*, 2nd ed. (New York: toExcel, 1999).
37. Jorgenson, Ho, and Stiroh, "A Retrospective Look at the U.S. Productivity Growth Resurgence," 12.
38. Jorgenson and Griliches, "The Explanation of Productivity Change"; Jorgenson and Fraumeni, "The Accumulation of Human and Nonhuman Capital"; Jorgenson, Gollop, and Fraumeni, *Productivity and US Economic Growth*; Jorgenson, Ho, and Stiroh, "A Retrospective Look at the U.S. Productivity Growth Resurgence."
39. Jorgenson, Gollop, and Fraumeni, *Productivity and US Economic Growth*, 92–3.

Table 5.1: Characteristics of labor quality

Sex (s)	*Industry (continued)*
(1) male	(23) Apparel and related products
(2) female	(24) Lumber and woods products
	(25) Furniture and fixtures
Age (a)	(26) Paper and allied products
(1) 16–17 years	(27) Printing and publishing
(2) 18–24 years	(28) Chemicals and allied products
(3) 25–34 years	(29) Petroleum and coal products
(4) 35–44 years	(30) Rubber products
(5) 45 years and over	(31) Leather and leather products
	(32) Stone, clay, and glass products
Education (e)	(33) Primary metal products
(1) 1–4 years grade school	(34) Fabricated metal products
(2) 5–8 years grade school	(35) Machinery (except electrical)
(3) 1–4 years high school	(36) Electrical machinery
(4) 1 or more years college	(37) Transportation equipment
	(38) Instruments and related products
Industry (i)	(39) Miscellaneous manufactures
(A) Agriculture, forestry and fishing	(E) Transportation, communication and utilities
(B) Mining	(F) Wholesale trade
(C) Construction	(G) Retail trade
(20) Food and kindred products	(H) Finance, insurance and real estate
(21) Tobacco manufactures	(I) Personal and professional services
(22) Textile mill products	(J) Public administration

The index of sectoral labor input for industry i is a translog quantity index of sectoral employment cross-classified by the components of l

$$\ln L_i^t - \ln L_i^{t-1} = \sum_l \overline{v}_{il} \left(\ln N_{il}^t - \ln N_{il}^{t-1} \right) \tag{5.1}$$

In equation (5.1) weights are given by the average share of each component in the value of sectoral labor compensation. These value shares are calculated on the basis of sectoral employment and compensation per worker (p_{il}), both classified by sex, age and education

$$\overline{v}_{il} = \frac{1}{2} \left(v_{il}^t + v_{il}^{t-1} \right), \tag{5.2}$$

and

$$v_{il} = \frac{p_{il} \cdot N_{il}}{\sum_l p_{il} \cdot N_{il}} \tag{5.3}$$

The sectoral index of labor input can also be expressed as the product of sectoral employment (N_i) and an index of sectoral labor quality (Q_i)

$$L_i^t = Q_i^t \cdot N_i^t \tag{5.4}$$

where total sectoral employment is defined as the unweighted sum of its components

$$N_i^t = \sum_l N_{il}^t \tag{5.5}$$

Rearranging terms in equation (5.4), taking logs and substituting the index for labor input by (5.1) provides a direct measure of the change in sectoral labor quality between period $t-1$ and t

$$\ln Q_i^t - \ln Q_i^{t-1} = \sum_l \overline{v}_{il} \left(\ln N_{il}^t - \ln N_{il}^{t-1} \right) - \left(\ln N_i^t - \ln N_i^{t-1} \right) \tag{5.6}$$

The index of labor quality thus reflects the difference between the growth rates of the compensation-weighted index of labor input and sectoral employment.

The derivation of the total economy, or multi-sectoral (e.g. total manufacturing) index of labor input is very similar to the method described above. The principle is identical, but labor input is now cross-classified across industry as well as the original gender, age and education characteristics

$$\ln L^t - \ln L^{t-1} = \sum_i \sum_l \overline{v}_{il} \left(\ln N_{il}^t - \ln N_{il}^{t-1} \right) \quad (5.7)$$

The total economy labor quality index is then given by

$$\ln Q^t - \ln Q^{t-1} = \sum_i \sum_l \overline{v}_{il} \left(\ln N_{il}^t - \ln N_{il}^{t-1} \right) - \left(\ln N^t - \ln N^{t-1} \right) \quad (5.8)$$

The drawback of this approach is that it requires highly disaggregate data on employment and compensation, generally not available in the published census reports or secondary sources for the early twentieth century. Fortunately, the Integrated Public Use Microdata Series (IPUMS) has made samples from the decennial population censuses publicly available, providing detailed records for nearly 10 million individuals between 1900 and 1950.[40] I utilize the microdata from this source to construct my measure of labor quality. As previously noted, the 1900–1930 censuses did not inquire into either the educational attainment of the general population or the compensation of workers and employees.[41] The 1940 census was the first census of its kind to ask about schooling, labor compensation and working hours to all citizens surveyed. In the wake of the depression the 1940 population census dedicated a substantial part of its inquiry into the issue of employment and productivity, making it an ideal starting point for this study.

To overcome these data issues I follow a two-tiered approach to the labor quality estimation. First, educational attainment is estimated at the micro level for the 1900, 1910, 1920 and 1930 census samples on the basis of the 1940 returns. I utilize a logistic regression to categorize the individuals included in the early censuses into the four educational categories shown in table 5.1. Second, I construct an employment matrix that groups workers according to their (predicted) educational attainment, gender, age and industry. In addition, I assemble a labor-compensation matrix on the basis of the 1940 census sample; again cross-classified by the characteristics listed in table 5.1. On the basis of the translog quantity indices (5.6) and (5.8), I estimate labor quality at the sectoral and total economy level. Before discussing the main results, a brief overview of the basic methods behind the estimation of educational attainment and a description of the main variables is given below.

40. Ruggles et al., *Integrated Public Use Microdata Series*.
41. This lack of data on the average years of schooling prior to 1940 is also likely to have been the reason why Kendrick chose to derive his labor quality on the basis of occupational characteristics instead of educational attainment.

Logistic regression

For the first stage of this study, I estimate the educational attainment for an individual on the basis of his or her occupation, gender, age and place of residence. On the basis of this approach I take both the long-run changes in the average years of schooling as well as the effects of changes in the occupational structure and the gender/age composition of the workforce into account. Using this procedure I estimated educational attainment at the micro level, allowing me to subsequently use the Jorgenson approach to study labor-quality change not just at the total economy level – as was the case for the previous studies – but also for individual industries and sectors.

For the estimation of educational attainment I opted for a logistic regression. The main advantage of this method is that it can cope with the limited number of responses educational attainment assumes in my model, while its results are still relatively easy to interpret.[42] Running a basic OLS on a categorical response variable would surely violate the standard assumptions of normality and homoscedasticity. In addition, predictions based on an OLS model are very likely to fall outside the feasible range of responses for the educational attainment variable. A predicted value of say -1 or 5.5 when there are only four categories of education does not make any economic sense and would be highly impractical in the second stage of the labor quality assessment.

For the logistic regression I predict the likelihood that an individual belongs to a specific educational category. If just two categories were allowed (e.g. [1] primary education only and [2] high school and above) I could estimate the probability that an individual i belongs to the first category, i.e. $P(Y_i = 1)$. This probability should be bounded by 0 and 1, continuous and nonlinear; conditions which are all met by a logistic, or logit transformation. In the logistic transformation, I first calculate the odds ratio and then take natural logs. The odds ratio is expressed as the likelihood of an occurrence (the individual belonging to a specific group) relative to the likelihood of a nonoccurrence (the individual not belonging to this group). Following this transformation I then assume a linear relationship between the logit dependent variable and the independent variables

$$\text{logit}[P(Y_i = 1)] = \ln\left[\frac{P(Y_i = 1)}{P(Y_i \neq 1)}\right] = \alpha + \beta X_i \tag{5.9}$$

As illustrated above, I actually include four educational categories in my model. Given the ordered nature of my response variable, I can use a similar principle to estimate the *cumulative* probability instead. The cumulative probability for the first category

42. P. McCullagh and J. Nelder, *Generalized Linear Models*, 2nd ed., Monographs on Statistics and Applied Probability 37 (London: Chapman / Hall, 1989).

would simply be $P(Y_i = 1)$, while the cumulative probability for the second response category is $P(Y \leq 2)$ which is equal to the sum of $P(Y_i = 1)$ and $P(Y_i = 2)$. The cumulative probability for the third category is $P(Y \leq 3)$, but the fourth and last response category is 1 by definition. Since all individuals that are not part of either the first, second or third category will be part of the fourth category, I can thus exclude this last category from the model.[43] In the final model, the cumulative probabilities require both a category-specific β_j as well as a separate intercept α_j; see equation (5.10).

$$\text{logit}[P(Y_i \leq j)] = \ln\left[\frac{P(Y_i \leq j)}{P(Y_i > j)}\right] = \alpha_j + \beta_j X_i, \qquad j = 1, 2, 3 \tag{5.10}$$

Census samples and variables

For the estimation of the logistic regression model I rely exclusively on the 1940 1-percent sample included in the IPUMS data-set. This sample is limited to include only those citizens aged 16 years and above, leaving approximately 975,000 observations for the regression. The data set includes a measure of the highest year of schooling or degree completed. As illustrated in table 5.1, I reclassify this variable to encompass four distinct educational attainment classes: [1] 1–4 years of grade school, [2] 5–8 years of grade school, [3] 1–4 years of high school (grades 9–12) and [4] 1 or more years of college/university.[44] This categorizations means an individual included in the third educational class has thus completed at least one year of high school while not having completed a full year in college or university. I opted for this condensed classification, as it still allows me to specifically study Goldin and Katz' 'high school revolution' and its impact on US productivity growth while, at the same time, limiting the number of response categories for the regression.

Following the literature on US labor quality, I mark four variables as important predictors of educational attainment, namely: occupation, birth cohort, gender and region. The relation of occupation to educational attainment is illustrated in table 5.2. Here the eleven main occupational groups and their distribution among the three educational classes are depicted.[45] Table 5.2 shows that the probability of a professional (e.g. engineers, economists) having attended high school was substantially greater than was the case for the average laborer.[46] Similarly, the percentage of operatives

43. Below I generally report the probability an individual belongs to a specific response category instead of the cumulative probability. The category specific probability for j can easily be derived as the difference between the cumulative probability for category j and $j-1$: $P(Y_i = j) = P(Y_i \leq j) - P(Y_i \leq j-1)$.

44. Note that if the individual only attended nursery school or did not attend school at all he/she is included in the first group: 1–4 years of grade school. See IPUMS variable $EDUC$ for further details; Ruggles et al., *Integrated Public Use Microdata Series*.

45. See IPUMS variable $OCC1950$ for further details; ibid.

46. Goldin and Katz show similar figures for the Iowa state census in 1915, confirming the findings in table 5.2 for an earlier year; see, Goldin and Katz, *The Race Between Education and Technology*, 170.

Table 5.2: Educational attainment and occupation (1940)[a]

		% that attended high school				
id	*occupation*	*aged 16–24*	*aged 25–34*	*aged 35–44*	*aged 45–54*	*aged 55–64*
1	professional, technical	95	90	86	82	82
2	farmers (owners and managers)	32	22	17	13	12
3	managers, officials, and proprietors	79	64	50	43	39
4	clerical staff	83	69	60	51	48
5	sales workers	82	68	59	48	45
6	craftsmen	56	36	26	22	18
7	operatives	43	29	22	19	16
8	service workers (household)	46	25	16	14	13
9	service workers (other)	30	19	16	17	7
10	laborers	52	32	22	18	16
11	unemployed/retired	27	14	10	8	8

[a] The results above are taken from the 1940 US Census of Population and are for men only. See main text for further details.

(e.g. spinners, apprentices) that have either attended or finished high school is over twice as low compared to the average for clerical staff (e.g. cashiers, telephone operators). Table 5.2 also shows that educational attainment decreases with age, or more specifically birth cohort. Nonetheless, the ranking of high school attendance between the occupations remains fairly stable; particularly the professional, managing, clerical and sales positions prove to be high-skill occupations, regardless of the age of the individual. Although the data in table 5.2 relates exclusively to men, the rank order of the different occupations is robust against both changes in gender as well as the state of residence.

The importance of gender and year of birth is illustrated by Goldin and Katz.[47] As discussed in the introduction, they observe a rapid increase in the average years of schooling throughout the late nineteenth and early twentieth century. Each successive cohort spent a substantially greater number of years in school compared to the previous generation; between 1876 and 1951 the average years of schooling rose by 0.82 years per decade. As noted above, this trend is also reflected in table 5.2, which shows a clear upward trend in high-school attendance for individuals in occupations born in the later cohorts.

In addition, Goldin and Katz show that women generally attended school for longer than men did throughout most of the early twentieth century. This was, they claim, "in large part because they attended and graduated from high school to a greater degree

47. ibid., 18–22.

[while] attending college at about the same rate as did men."[48] The gender variable was taken directly from the IPUMS data-set while the year of birth was rounded off to the nearest decade. The relative distance in decades to 1930 was then taken as the birth cohort measure.[49]

Lastly, Goldin and Katz note the regional differences in educational attainment. They point to widespread differences in state support and show that the rise in both high school graduation rates as well as college enrollment rates for states in the North and West of the country were considerably more impressive than for the rest of the nation.[50] I incorporate a variable in my model that differentiates between the four main regions of the country: (1) the South, (2) the Midwest, (3) the West, and (4) the Northeast.[51]

In the second stage of this study I again rely on the 1940 sample to estimate relative compensation per labor category. Here I limit the sample to include only those citizens between the ages of 16 and 84 having worked at least 48 weeks in the previous year and earning an income greater than 0.[52] Overall, I am left with well over 210,000 individual observations for the labor-compensation matrix. These individuals are allocated to the cells of the matrix cross-classified by gender, age, education and industry as summarized in table 5.1. Compensation is reported in the census as the respondent's total pre-tax wage and salary income for the previous year, expressed in current dollars.[53] To obtain total personal income, which also includes non-wage income, I multiplied the 1940 compensation figures by the ratio between wage and salary income and total personal income taken from the 1950 census returns.[54] Non-wage income generally represented only a small part of total personal income in my sample, with the notable exception of the agricultural sector.

For the construction of the employment matrix I use the IPUMS 1-percent census samples for the decades between 1900 and 1950. To estimate educational attainment I include the occupation, birth cohort, gender and region variables discussed earlier, supplemented by data on the age of the individual and industry in which he/she is engaged.[55] The employment sample is limited to include only those citizens between the ages of 16 and 84, who are engaged in one of the sectors listed in table 5.1. For the

48. Goldin and Katz, *The Race Between Education and Technology*, 19.

49. An individual born in 1901 would thus be assigned a value of 3 as birth cohort, regardless whether I observe this individual in the 1920 or 1950 census. For details on gender and age see the IPUMS variables *SEX* and *AGE* respectively; Ruggles et al., *Integrated Public Use Microdata Series*.

50. Goldin and Katz, *The Race Between Education and Technology*, 201–8, 271–7.

51. See IPUMS variable *REGION* for further details; Ruggles et al., *Integrated Public Use Microdata Series*.

52. C. Goldin and L. Katz, "The Returns to Skill in the United States Across the Twentieth Century," *National Bureau of Economic Research Working Paper* 7126 (1999): 1–49.

53. See IPUMS variable *INCWAGE* for further details; Ruggles et al., *Integrated Public Use Microdata Series*.

54. See IPUMS variable *INCTOT* for further details; ibid.

55. See IPUMS variable *IND*1950 for further details; ibid.

employment-matrix my data-set includes 3,135,000 individual observations. The samples for the logistic regression, the compensation matrix and the employment matrix are all weighted by the IPUMS 'person weight' variable.[56]

5.4 Results

In this section I discuss the main results from the labor quality estimation. As a first step I estimate educational attainment on the basis of a logistic regression. The results from this regression and a detailed discussion of various specifications of the model are left to appendix 5.A. On the basis of the logistic regression, I confirm the findings by Goldin and Katz that great leaps were made during the early twentieth century toward mass secondary schooling. I also establish that the greatest gains for college attendance occurred only later in the century. In addition, I observe significant regional differences in educational attainment. After correcting for occupation, region and birth cohort the regression reveals a slightly increased probability for women to have attended high school. Reversely, the probability for them to have also attended college was lower.

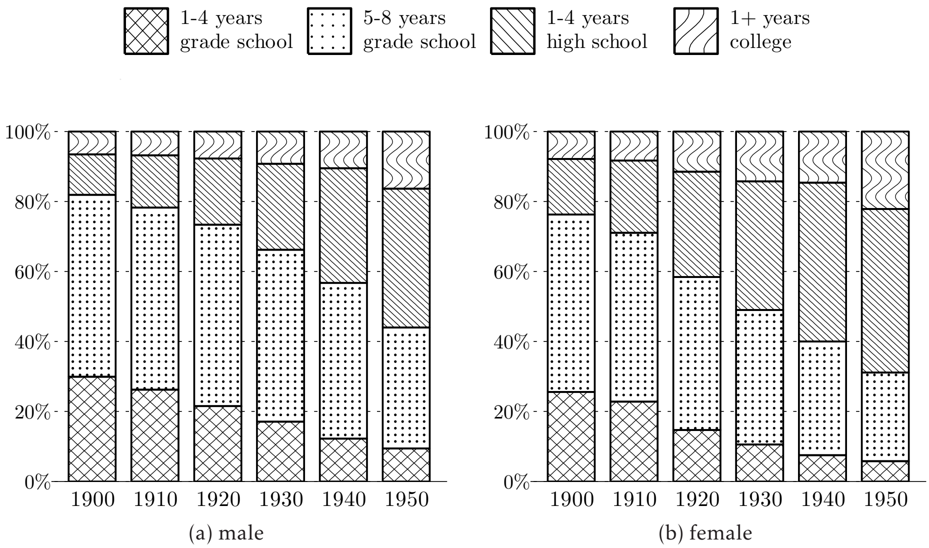
On the basis of the model described in appendix 5.A and the microdata from the IPUMS database I can predict the educational attainment for all individuals in the US workforce for the census years between 1900 and 1930. In addition, the census figures allow me to map the changes in gender composition and experience over the first half of the twentieth century. Below, I present the labor composition figures for the entire US workforce, which will form the basis for my labor quality index presented at the end of this section.

Labor composition

Figure 5.2 depicts the predicted results for the pre-1940 census years, as well as the observed values of educational attainment for 1940 and 1950. The figures are presented at the total economy level, separately for both men and women. The results reveal a remarkable increase in the share of employees and workers that attended either secondary or tertiary education. My estimates show that in 1900 approximately 80 percent of the male workforce had not received an education beyond grade school, whereas only a little over 6 percent had attended college. By 1950 the primary education group had almost halved to just over 40 percent, while the tertiary education group had expanded to 16 percent. The high school category experienced the most dramatic expansion, however. For men it rose from approximately 12 percent in 1900

56. See IPUMS variable *PERWT* for further details; ibid.

Figure 5.2: Educational attainment of the workforce (1900–1950)[a]



[a] The figures for 1900–1930 are estimated on the basis of the logistic regression discussed in appendix 5.A.

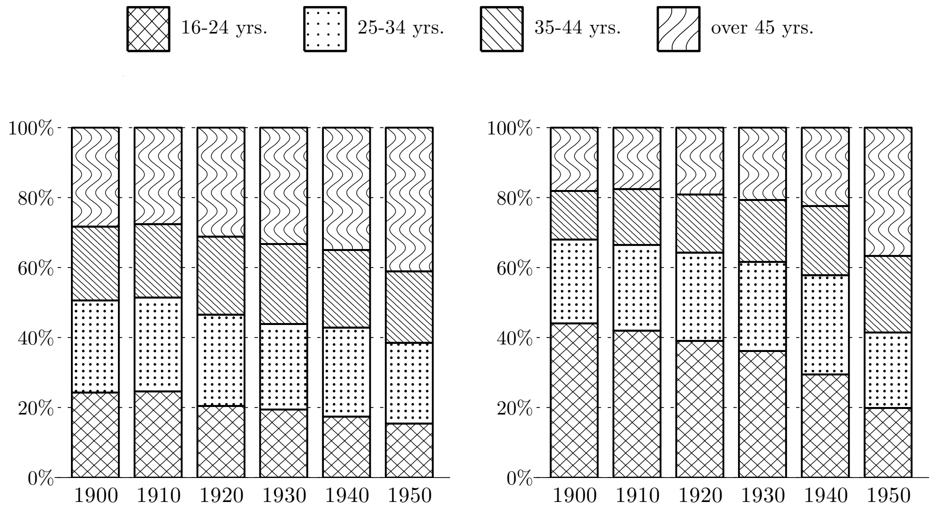
to 40 percent in 1950. For women this category had already expanded to 45 percent by 1940, up from 16 percent in 1900.

The right panel of figure 5.2 shows that throughout this period woman workers not only experienced an equally impressive rise in educational attainment, they were, on average, also slightly better educated than their male counterparts. Besides the fact that women attended school for longer than most men did, those that chose to participate on the labor market were also better educated than the women that stayed at home.[57] Women were primarily employed as household service workers and, from 1920 onwards, in clerical occupations (typists, secretaries, etc.). Generally, the clerical professions attracted women with an above average level of educational attainment. The majority of men, on the other hand, were still engaged as either laborer, operator or farmer prior to the Second World War.

Figure 5.3 reports the age of the total labor force, again for men and women separately. Although the evolution of the average age of the US workforce – which serves as a proxy for the overall experience – was naturally not as dramatic as was the case for educational attainment, figure 5.3 still demonstrates a steady increase during the period 1900–1950. For male workers, the outermost category (45 years and over) ex-

57. Goldin and Katz, *The Race Between Education and Technology*, 19.

Figure 5.3: Age of the workforce (1900–1950)



(a) male (b) female

panded from approximately 30 percent of the labor force during the start of the period to 40 percent in 1950. The trend for female workers was more pronounced as, particularly following the Second World War, they continued to work at higher ages. This is most evident from the change in the innermost experience category (16–24 years) which contracted from approximately 45 percent in 1900 to 20 percent in 1950.

The increased willingness of women to continue to work, even after marriage, and the growing demand for female employees particularly in the clerical occupations ultimately resulted in a steadily rising share of women in the workforce. In 1900 approximately 18 percent of workers was female, which rose to 24 percent in 1940 and increased even further after the war to roughly 30 percent. Even though the rising share of women accelerated the growth of the educational attainment level of the labor force, overall it tended to depress the growth of labor quality, as I will show in section 5.5 below.

1940 labor compensation

The various labor categories, as distinguished by gender, educational attainment and experience, described in the previous section, can be combined into a constant quality index of labor. As illustrated in section 5.3, I aggregate these groups using 1940 labor-compensation weights. The full labor-compensation matrix – which distinguishes be-

Table 5.3: Labor compensation, total economy ($, 1940)[a]

		age				
sex	*education*	*16–17*	*18–24*	*25–34*	*35–44*	*45+*
male	1–4 years grade school	203	381	647	911	991
male	5–8 years grade school	341	661	1,138	1,458	1,482
male	1–4 years high school	472	891	1,423	1,843	1,952
male	1 or more years college	...	1,333	2,115	2,733	2,825
female	1–4 years grade school	157	247	371	469	505
female	5–8 years grade school	236	435	641	751	761
female	1–4 years high school	328	591	847	1,015	1,024
female	1 or more years college	...	816	1,172	1,431	1,503

[a] Labor compensation is based on the 1940 IPUMS 'wage and salary income' (INCWAGE) adjusted to 'total personal income' (INCTOT) on the basis of figures on non-wage income from the 1950 census returns. For the full industry decomposition of labor compensation see appendix 5.B.

Source: S. Ruggles et al., *Integrated Public Use Microdata Series*, 5.0 (Minneapolis: University of Minnesota, 2010).

tween gender, age, education and industry – is shown in appendix 5.B, but table 5.3 presents an excerpt of the labor compensation figures for the total economy.

The wage structures in 1940 was characterized by large inequality.[58] The figures in table 5.9 demonstrate that men earned consistently more than women for all labor categories, ranging from about 30 percent for the youngest workers to 100 percent for the older and more skilled workers. The wage gap between the secondary and upper-primary education class ranged from about 25 to 40 percent, while the college/high-school gap lay between 45 and 65 percent. Overall an experienced, college educated, male employee could earn up to 11 times the wage of a 18–24 year old women with 4 or less years of grade school.

Ideally, I would like to allow the weights for my labor quality index to vary over time, reflecting potential changes in relative compensation between the labor categories. Unfortunately, the censuses prior to 1940 did not inquire into either wages nor earnings, impeding the accurate measurement of labor compensation for these earlier decades. However, Goldin and Katz demonstrate that the wage structure observed in 1940 was fairly typical for the prewar period.[59] Although, on the basis of scattered evidence on wages from various sources they observe a gradual compression of the wage distribution for production workers between 1890 and 1940, Goldin and Katz conclude that the gap in the skilled/unskilled wage level for 1920 was virtually identical

58. See also, Goldin and Katz, *The Race Between Education and Technology*, 44–88.
59. ibid., 53–7.

Table 5.4: Labor quality index, main sectors (1900=100)

sector	*1900*	*1910*	*1920*	*1930*	*1940*	*1950*	Δln%
Agriculture, forestry and fishing	100	101	110	113	119	130	*25.9*
Mining	100	101	105	111	116	125	*22.0*
Construction	100	98	104	105	105	114	*13.0*
Manufacturing	100	102	110	115	119	129	*25.8*
Transportation, comm. and utilities	100	99	103	109	118	118	*16.9*
Wholesale trade	100	96	97	99	100	102	*2.0*
Retail trade	100	98	101	103	103	104	*4.2*
Finance, insurance and real estate	100	92	89	90	95	92	*-8.0*
Personal and professional services	100	100	111	115	120	130	*26.2*
Public administration	100	99	93	103	102	95	*-5.1*
Total economy	100	107	118	125	131	143	*35.8*

Source: see text.

in comparison to 1940.[60] On the basis of this evidence I feel confident using solely the 1940 compensation figures as weights for the construction of my labor quality index.

Labor quality

Joining the labor composition data with the labor-compensation figures presented in the previous paragraph yields my final labor-quality indices. As discussed in section 5.3, labor quality is defined as labor input per worker and represents changes in the composition of the workforce.[61] Table 5.4 displays the figures for the entire American labor force between 1900 and 1950, in addition to more detailed statistics for the main economic sectors. At the total economy level, labor quality exhibited a steady increase for the entire period. The average growth between 1900 and 1950 was approximately 0.72 percent per annum, primarily reflecting the rapid rise in the share of the workforce that attended either high school or college.

Table 5.4 also illustrates that there were substantial differences in the growth rates of labor quality between the major economic sectors. Primarily within the service sector I observe notable variations in the development of labor quality. The transportation, communication and utilities as well as the personal and professional services exhibited strong growth. The finance, insurance and real estate (FIRE) and public administration sectors on the other hand exhibited a decline in labor quality, albeit a slow one. Employment in the government branch increased rapidly during the first half of the twentieth century; a small, generally highly educated labor force in 1900 expanded

60. ibid., 55, 59–63.
61. Jorgenson, Ho, and Stiroh, "A Retrospective Look at the U.S. Productivity Growth Resurgence," 8.

quickly and, following the wars, was supplemented with a younger, less experienced cohort. In addition, the share of women in this sector grew rapidly, particularly during the 1930s and 1940s. Section 5.5 below will discuss the contribution of experience, gender and educational attainment to labor-quality change in further detail.

To illustrate the *level* differences in labor quality between the sectors of the economy, I can utilize an approach very similar to the one described in section 5.3. Instead of measuring the structural change of employment in each of the labor categories over time, I analyze the difference in the employment structure between sector i and a base, or reference sector b. The subscript l is again used to represent all labor characteristics listed in table 5.1, except for industry. The log difference in employment for each component is now weighted by the average shares in sectoral labor compensation for both sectors i and b

$$\ln Q_i^t - \ln Q_b^t = \sum_l \overline{v}_l^t \left(\ln N_{il}^t - \ln N_{bl}^t\right) - \left(\ln N_i^t - \ln N_b^t\right) \tag{5.11}$$

where

$$\overline{v}_l^t = \frac{1}{2}\left(v_{il}^t + v_{bl}^t\right) \tag{5.12}$$

In table 5.5 I show the labor quality levels for the first and last years in my sample, with the total economy as the reference sector. Levels for the intermediary decades are shown separately in appendix 5.D. The comparison confirms the high level of labor quality in public administration around 1900 and the subsequent decline (relative to the total economy) during the first half of the twentieth century. This relative decline is also evident for most of the other sectors with high initial levels of labor quality. Overall, for the period between 1900 and 1950, the US experienced a gradual contraction of the skill-gap between its major economic sectors.

The agricultural, mining and manufacturing sectors benefited most from the narrowing of the gap in sectoral labor quality. The agriculture, forestry and fishing sector – traditionally a low-skill sector, as shown in table 5.5 – witnessed a steady improvement in the composition of its labor force. Although this was the only major sector to experience an absolute decline in labor numbers, the outflow of workers consisted primarily of young, lesser educated laborers. This ultimately led to a modest improvement of the agricultural sector's labor quality level. As shown in table 5.4, growth in labor quality for the mining and manufacturing sectors was also quite fast compared to the sectoral average. This primarily reflected the ability of these sectors to attract more experienced and skilled labor than any of the other sectors, as I will show next.

Table 5.5: Labor quality levels, main sectors (total economy=100)

sector	*1900*	*1950*
Agriculture, forestry and fishing	90	93
Mining	98	103
Construction	110	101
Manufacturing	96	99
Transportation, comm. and utilities	105	105
Wholesale trade	130	109
Retail trade	113	96
Finance, insurance and real estate	132	104
Personal and professional services	93	96
Public administration	125	102
Total economy	100	100

Source: see text.

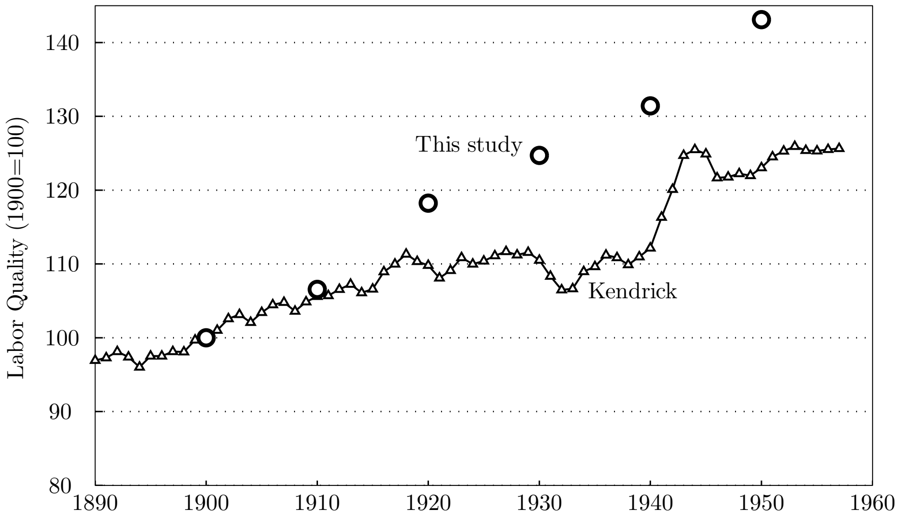
5.5 Decomposition and long-run trends

In this section I will elaborate on the results of the previous section and discuss their relevance in relation to the ongoing human capital debate. First, I will compare my new estimates to the figures by Kendrick and Denison. Here I conclude that Kendrick's index of labor quality is incompatible with evidence on the increase in the average years of schooling (as outlined by Goldin and Katz) and that my own figures appear to provide a much better fit in this respect. Next, I decompose the labor quality index to assess the direct impact of education, the change in gender composition, age and shifts in the industrial structure. I conclude that the educational reforms of the late nineteenth and early twentieth century as well as structural shifts were the main source of the continuous quality growth of the American workforce. All sectors shared in the improvements resulting from the educational reforms, even though the impact of this and the other labor characteristics on labor input differed widely between them. Lastly, I link my estimates to the post-war figures by Jorgenson et al. and discuss the long-run development of labor quality. Again, education plays a pivotal role, both in the development of labor input as well as aggregate production.

Labor quality in perspective

When comparing the new figures to the original labor quality index by Kendrick we can observe substantial differences in the estimated trend over the course of the early

Figure 5.4: Labor quality, new estimates (1890–1960)



Source: J. Kendrick, *Productivity Trends in the United States* (Princeton: National Bureau Economic Research, 1961), 328–9; This study, see table 5.4.

twentieth century.[62] Figure 5.4 plots Kendrick's national economy numbers against my total economy figures listed in table 5.4. Kendrick's figures report a markedly different rate of advance for particularly the interwar and the Second World War years. My labor quality index suggest a steady rate of growth of approximately 0.7 percent per year between 1900 to 1950. Kendrick estimated a constant increase of roughly 0.5 percent before 1920, little to no growth between 1920 and 1940 and a very rapid increase during the war years.

As previously noted, Kendrick's labor quality index does not accord well with the observed continuous increase in the average years of schooling.[63] Particularly the stagnation of labor quality during the 1920s and 1930s is not reflected in the development of the rate of school attendance over course of the early twentieth century and would suggest a structural divide between the educational attainment of the workforce and the population as a whole. The new estimates provide no evidence for such a division. Instead, I observe an almost uninterrupted increase in labor quality throughout the entire interwar period for the agricultural, industrial and some service sectors. Productivity studies relying on Kendrick's labor input figures – Field's work on American inter-war productivity and technological change for instance – are thus bound to over-

62. Kendrick, *Productivity trends in the United States*, 265–8, 328–30.
63. Goldin and Katz, *The Race Between Education and Technology*, 20.

state the growth unaccounted for by factor inputs (i.e. TFP) by quite a margin.[64]

The pre-war labor quality estimates by Denison compare more favorably to my own.[65] Following Gordon, I amended Denison's estimates to exclude the arbitrary adjustment for ability and only took the increasing school years per person into account (thus ignoring the impact of increasing school days per year).[66] The resulting figures project a growth of labor quality of 0.6 percent per year for the 1913–1928 period and 0.5 percent annually between 1928 and 1950.[67]

Education, gender and experience

To fully assess the role played by education – both for the development of labor input as well as aggregate production – I can decompose the labor quality index into its underlying constituents. Ho and Jorgenson suggest a breakdown of the index on the basis of its distinctive characteristics.[68] They propose the construction of partial indices of labor input in which only a subset of the characteristics is incorporated. To construct such a partial index, I sum the number of workers and the corresponding value shares over some of the characteristics and construct a translog index over the remaining characteristics.[69]

Previously, I used a single subscript (l) to represent the categories of labor input cross-classified by all characteristics except for industry. Below I use a separate subscript for each of the individual characteristics: two sexes, represented by the subscript s; five age-groups, represented by a; four educational classes, represented by e; and twenty-nine industries, still represented by i. The partial labor input index for gender is then given by

$$\ln L_s^t - \ln L_s^{t-1} = \sum_s \overline{v}_s \left(\ln \sum_a \sum_e \sum_i N_{isae}^t - \ln \sum_a \sum_e \sum_i N_{isae}^{t-1} \right) \tag{5.13}$$

Equation (5.13) is based on equation (5.7), the basic labor input equation introduced in section 5.3. However, now the compensation shares $\overline{v}_s$ solely distinguish between the two gender categories and is multiplied by the log change of male and female workers respectively. The resulting partial labor input index only reflects changes in the relative share of men and women in the workforce and ignores the effects of the

64. Field, "The Most Technologically Progressive Decade of the Century"; Field, "Technological Change and US Productivity Growth."

65. Denison, *The Sources of Economic Growth in the United States*; Denison, *Trends in American Economic Growth*.

66. Gordon, "US Economic Growth Since 1870: One Big Wave?," 124.

67. Gordon, "Interpreting the One Big Wave in US Long-Term Productivity Growth."

68. M. Ho and D. Jorgenson, "The Quality of the U.S. Work Force, 1948–95," *Harvard University Unpublished Working Paper* 1 (1999): 12.

69. Jorgenson, Gollop, and Fraumeni, *Productivity and US Economic Growth*, 269.

Table 5.6: Labor-quality growth decomposition, main sectors (ln%, 1900–1950)[a]

		characteristics				
sector	*total*	*e*	*a*	*s*	*i*	*resid.*
Agriculture, forestry and fishing	25.9	17.0	8.4	-0.6	...	1.2
Mining	22.0	11.5	7.7	-0.9	...	3.7
Construction	13.0	8.6	2.5	-0.7	...	2.5
Manufacturing	25.8	10.9	12.4	-5.9	7.8	0.6
Transportation, comm. and utilities	16.9	7.3	8.9	-6.0	...	6.6
Wholesale trade	2.0	5.4	0.6	-9.3	...	5.3
Retail trade	4.2	4.4	7.7	-12.5	...	4.6
Finance, insurance and real estate	-8.0	6.0	-5.4	-17.5	...	8.9
Personal and professional services	26.2	15.5	13.7	3.9	...	-6.9
Public administration	-5.1	6.1	-10.5	-4.2	...	3.4
Total economy	35.8	17.6	7.7	-6.4	20.4	-3.4

[a] May not sum to total due to rounding. The full growth decomposition, including the second, third and fourth order effects, is listed in appendix 5.C.
Source: see text.

other characteristics. As before, labor-quality growth can still be derived as the difference between the growth rates of the compensation-weighted, partial index of labor input and employment.

Partial indices for all four characteristics can be computed, which are referred to as *first-order* indices. In addition to these first-order indices, second-order indices of labor input can also be defined. These depend on any two characteristics of labor input, by adding employment and the corresponding value shares over other characteristics and again constructing a translog index.[70] Similarly, I can define third- and fourth-order indices. There are six second-order indices, four third-order indices and one fourth-order index. The fourth-order index reflects compositional shifts among all characteristics, as in equation (5.7).

The last row in table 5.6 reports the results from the decomposition of labor-quality growth for the entire American labor force. The first column in this table displays the log growth over the entire period, while the next columns report the partial, first order indices for education (e), age (a), sex (s) and industry (i) respectively. The final column reports the sum of the residual, second-, third- and fourth-order effects. The full decomposition, including the higher-order indices, is given in appendix 5.C.

Table 5.6 shows that the growth of labor quality, at the total economy level, appeared to be driven primarily by the change in educational attainment and shifts in

70. Jorgenson, Gollop, and Fraumeni, *Productivity and US Economic Growth*, 270.

the industrial structure. The contribution of education was positive for all decades and showed a clear rising trend over time, reflecting the findings by Goldin and Katz.[71] The relocation of labor from low-skill/low-productive sectors (e.g. agriculture) to high-skill sectors (e.g. trade and FIRE), reflected an improvement in the utilization of the workforce, greatly raising the potential output per worker. To a lesser extent, the gradual rise in the experience level of the American workforce, as illustrated by the increase in the average age shown in figure 5.3, also positively contributed to labor-quality growth.

The shift in employment between main economic sectors was quite pronounced.[72] In 1900 the agricultural sector employed approximately 40 percent of the total workforce; the industrial and service sector accounted for 23 and 37 percent of employment respectively. By 1950 the share of agriculture in total employment had decreased to just over 10 percent. The service sector, on the other hand, had expanded its share to 58 percent, while the industrial sector engaged 31 percent of the workforce. As shown in appendix 5.B, labor compensation in the agricultural sector was well below average when compensated for differences in gender, education and age. In contrast, the average earnings in the service sectors were considerably higher, which suggests a greater marginal productivity of a service-employee with the same characteristics as a farm-worker. The shift of employment out of agriculture thus greatly added to the productivity potential of the total American workforce – contrary to the claim in this respect by Denison.[73]

In contrast, the rising share of women in the labor force tended to depress the growth of labor quality. Particularly the period between 1940 and 1950 – as a result of the war effort – observed a marked increased in the number of female workers. This, according to my estimates, reduced labor-quality growth by almost 3.3 percent in the course of the 1940s. It should be noted, however, that the negative contribution of the change in the gender composition follows from my assumption that the relative wage for a particular labor category reflects its relative contribution to labor input. As shown in appendix 5.B, women earned consistently less than men, which I thus assume indicates that their marginal productivity also fell short of that of male workers. The wage gap may overstate the actual differences, however, as social factors are likely to have played a role during wage negotiations, detrimentally affecting female workers' wages. Still, data from the second half of the twentieth century reveals that, even though women did gain on men, the wage differential always favored male employees. the observed wage gap may thus reflect genuine differences between men and women

71. Goldin and Katz, *The Race Between Education and Technology*.
72. Broadberry, "How Did the United States and Germany Overtake Britain?," 385.
73. Denison, *The Sources of Economic Growth in the United States*, 209–10.

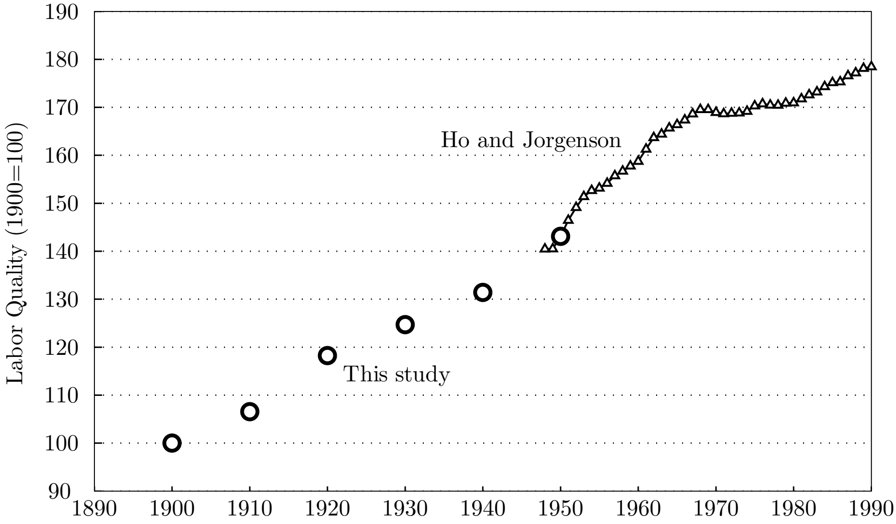
in physical characteristics, shorter hours worked by women and reduced experience for female employees (e.g. resulting from time taken off for child-rearing). Arguably, the numbers presented in table 5.6 thus provide a lower bound for the contribution of changes in the gender composition. The resulting labor quality index should therefore also be interpreted as a conservative estimate.[74] As illustrated in section 5.4, the rising share of women in the workforce did accelerate the growth of the overall educational attainment level however, which may explain the relatively high contribution of the education characteristic for the last decade in my sample.

In addition to the total economy figures, table 5.6 also presents the decomposition for the main sectors of the American economy between 1900 and 1950. Note that for all sectors except manufacturing the contribution of the industry characteristic is zero, as these sectors represent the lowest level of aggregation in my data-set, preventing any role for structural change. Again I observe that (1) educational attainment was the greatest contributor to labor-quality growth for almost all sectors, (2) the growth in the partial index for age was nearly always positive (except for public administration and FIRE), and (3) the change in gender composition always reduced labor-quality growth (except for personal and professional services). Nonetheless, particularly for the gender and age characteristics there were large inter-sectoral differences. Especially the service sectors attracted a substantial amount of female labor, while the manufacturing sector experienced the most rapid rise in the combined experience level of its workforce.

Overall, the decomposition exercise discussed above provides a useful assessment of the sources behind the labor-quality growth. I confirm Denison's finding for the total economy that the educational reforms of the late nineteenth and early twentieth century were a major source for the continuous quality improvements of the American workforce.[75] More in line with Kendrick, I also uncover a significant effect of structural change on the growth in total-economy labor quality.[76] Whereas Denison attributed a mere 0.02 percentage point annually to the reallocation of labor between sectors between 1909 and 1957, I estimate an annual contribution of 0.27 percent between 1900 and 1950.[77] All sectors shared in the improvements in educational attainment, although the impact of this and the other labor characteristics on labor input differed substantially between them. These findings all strengthen the recent narrative by Goldin and Katz who typify the twentieth century as the 'human capital century.'[78]

74. For further details on wage inequality in the US see, Goldin and Katz, *The Race Between Education and Technology*, 50 and Denison, *The Sources of Economic Growth in the United States*.
75. ibid., 265.
76. Kendrick, *Productivity trends in the United States*.
77. Denison, *The Sources of Economic Growth in the United States*, 209–10.
78. Goldin and Katz, *The Race Between Education and Technology*.

Figure 5.5: Labor quality, long-run estimates (1900–1990)[a]



[a] My figures for 1900–1950 were linked to the 1948–1990 figures by Jorgenson et al. *Source:* M. Ho and D. Jorgenson, "The Quality of the U.S. Work Force, 1948–95," *Harvard University Unpublished Working Paper* 1 (1999): 26; D. Jorgenson and B. Fraumeni, "Investment in Education and U.S. Economic Growth," *Scandinavian Journal of Economics* 94 (1992): S51–S70; This study, see table 5.4.

Long-run trends

Figure 5.5 displays the long-run development of American labor quality for the period between 1900 and 1990. I link my estimates to the post-war figures by Jorgenson et al., who apply a method compatible with the one used throughout this study.[79]

Following the Second World War, we can observe an acceleration in the growth of labor quality. For this period, Jorgenson and Fraumeni again stress the role of education, both for the development of labor input as well as aggregate production.[80] Between 1948 and 1969, labor quality contributed approximately 0.9 percentage points to overall productivity growth. However, the role played by labor quality lessened substantially in the 1970s and 1980s. Growth of the quality index decreased to just 0.3 percent per year, well below the trend observed in the pre- and post-war period.[81] The decline in labor-quality growth mirrored the slowdown of educational attainment observed primarily for Americans born between 1950 and 1975.[82] The latter again underscores the importance of labor quality and human capital accumulation in the

79. Ho and Jorgenson, "The Quality of the U.S. Work Force," 26; D. Jorgenson and B. Fraumeni, "Investment in Education and U.S. Economic Growth," *Scandinavian Journal of Economics* 94 (1992): S51–S70.
80. Jorgenson and Fraumeni, "Investment in Education and U.S. Economic Growth," S61.
81. ibid., S63.
82. Goldin and Katz, *The Race Between Education and Technology*, 22.

Table 5.7: Labor-quality growth decomposition, manufacturing industries (ln%, 1900–1950)[a]

			characteristics				
sic	*sector*	*total*	*e*	*a*	*s*	*i*	*resid.*
23	Apparel and related products	11.7	5.7	22.3	-15.9	...	-0.4
31	Leather and leather products	0.1	4.9	4.2	-15.8	...	6.9
25	Furniture and fixtures	9.6	7.6	2.7	-5.5	...	4.8
26	Paper and allied products	29.8	9.9	17.0	3.2	...	-0.2
28	Chemicals and allied products	23.3	14.5	9.1	-4.7	...	4.3
29	Petroleum and coal products	26.4	14.6	9.5	-4.3	...	6.6
36	Electrical machinery	24.9	8.4	22.7	-9.3	...	3.1
37	Transportation equipment	12.0	8.8	2.9	-4.9	...	5.2
D	Manufacturing	25.8	10.9	12.4	-5.9	7.8	0.6

[a] May not sum to total due to rounding. The full growth decomposition, including the second, third and fourth order effects, is listed in appendix 5.C.
Source: see text.

American productivity debate. The figures presented in this study are the first attempt I know of to provide a consistent measure of labor quality all the way back to the start of the century. This will allow researchers to further study the contribution of educational reform and overall changes in labor composition from a long-run perspective.

Manufacturing

As illustrated in table 5.4, manufacturing was one of the sectors with the fastest rate of labor-quality growth throughout the early twentieth century. The detailed industry data in the IPUMS data-set allowed me to further disaggregate labor quality for the manufacturing sector, the results of which are shown in table 5.7. This table contains only a selection of the manufacturing industries, the full list of industries is provided in appendix 5.C.

The detailed figures for manufacturing in the first column reveal similarly large inter-industry differences of labor-quality growth as those observed for the major sectors in table 5.4. Whereas, for example, labor quality in the furniture and fixture and leather industries progressed only slowly, the paper, petroleum and electrical machinery industries exhibited very rapid growth. The decomposition of labor-quality growth on the basis of gender, education and experience in table 5.7 sheds further light on the sources behind these diverging trends.

On the basis of this decomposition, I again conclude that the change in educational attainment was the main driver behind the growth of labor quality for most manufacturing industries. In contrast to the sectoral decomposition, however, I do observe substantially greater deviations in the relative contributions of gender, experience and even education across industries. In some cases the changes in the share of women engaged or shifts in the average age of the employees even eclipsed growth of labor quality as a result of educational change.

The slow growth of labor quality for the leather and apparel trades, and also the tobacco industry, was primarily the result of the rapidly rising share of women working in these industries. This development is clearly illustrated by the large negative contributions of gender in the decomposition for these industries. The ratio of female to male workers in the apparel industries, for instance, grew from approximately 1:1 in 1900 to 3:1 in 1950. The leather industries showed an equally impressive transformation; in 1900 just 14 percent of the workers were women, which expanded to over 40 percent in 1950. Even though other industries initially employed similar shares of female workers (e.g. textile mill products), I do not observe a comparable increase in the share of female workers over time. The apparel, leather and tobacco industries thus stand out as the above results appear to suggest that the production in these industries – by way of their use of capital or technology – has changed significantly over the course of the early twentieth century, making it more suitable to female labor.

This development can be illustrated on the basis of the decomposition introduced in section 5.4. Appendix 5.D list the results from the level decomposition for the manufacturing industries, with total manufacturing as the reference sector. To directly measure the contribution of, for instance, gender to inter-sectoral level differences, I can extend the level decomposition in equation (5.11) to include partial labor input indices that only reflect changes in the relative share of men and women in the workforce and ignore the effects of the other characteristics; in line with equation (5.13). Appendix 5.D also lists the resulting first-order indices for education, age and sex for all manufacturing industries.

The greatest gains from education were achieved within the chemicals and petroleum industries. Compared to the leather products industries, the difference in the rate of change in educational attainment for the petroleum industries alone is responsible for a gain in labor-quality growth of almost 10 percentage points. Together with printing and publishing, the petroleum industries engaged the greatest share of college educated employees at both the start of the century and in 1950 (approximately 25 percent in 1950). In contrast, for the same year, the share of tertiary educated employees was only 5 percent for the textile, apparel and leather industries. Generally, I observe that industries that employed a relatively large share of secondary and tertiary educated workers in 1900 maintained this advantage throughout the entire period of study. This is also reflected in the level decomposition shown in appendix 5.D. The partial index for education for the petroleum industry yields a level of 108 in 1950, whereas this index for textiles, apparel and leather lies between 94 and 95 for this year.

The importance of the last component, age, is particularly evident for the transportation equipment industry. This industry stood out at the start of the twentieth century as a result of its older and highly experienced labor force. In conjunction with a low share of female laborers and about average educational attainment, the transportation equipment sector had the highest level of labor quality compared to the other manufacturing industries in 1900 (see appendix 5.D). Given this high initial level of labor quality, the scope for improvements by way of attracting more experienced labor was limited, as illustrated by the low contribution of the experience characteristic for this industry in table 5.7. Since the contribution of the other two characteristics to labor-quality growth (education and gender) was comparable to the manufacturing average, the other industries began to slowly converge on the transportation equipment sector in terms of labor quality levels. Eventually, around 1930, it definitively lost its lead to the petroleum and machinery producing industries.

The development of labor composition, or lack thereof, for the transportation equipment industry as a whole is nicely summarized by the experience of the automobile industry. Prior to the introduction of Ford's assembly line in 1913, the fabrication of automobiles was a highly skilled job which was generally performed by a number of all-round mechanics. As noted by Goldin and Katz however, over the course of the early twentieth century "technological advances then led to standardized and completely interchangeable parts that were assembled in factories [...] by scores of less-skilled workers."[83] This illustrates both the initial high level of labor quality for the transportation sector, as well as the slow development of human capital over time.

As noted by Goldin and Katz it is very likely that new technologies alter the relative demand for different types of labor.[84] This technology-skill complementarity has also been associated with the electricity revolution of the early twentieth century.[85] When I compare the growth in labor quality to my sectoral estimates of technological change discussed in the previous chapter, I observe a mildly positive correlation between both measures.[86] For the period 1909–1939 the lumber, furniture and leather industries experienced an annual technological change of just over 1.0 percent – well below the average for manufacturing of 1.9 percent – while technology in the petroleum and

83. C. Goldin and L. Katz, "The Origins of Technology-Skill Complementarity," *Quarterly Journal of Economics* 113 (1998): 696.

84. Goldin and Katz, *The Race Between Education and Technology*, 91.

85. Goldin and Katz, "The Origins of Technology-Skill Complementarity"; L. Katz and R. Margo, "Technical Change and the Relative Demand for Skilled Labor: The United States in Historical Perspective," *National Bureau of Economic Research Working Paper* 18752 (2013): 1.

86. Excluding the transportation equipment sector, I find a correlation of 0.43 between the growth in labor quality and technological change in the period 1910–1940.

rubber industries increased by 2.7 and 4.7 percent per year respectively. The figures in appendix 5.C confirm that the growth of labor quality mirrored that of technological change for these particular industries. However, rapid technological change and labor quality increases do not always coincide. Transportation equipment, for instance, exhibited the fastest rate of technological change at 3.9 percent annually but experienced a below average rate of labor-quality growth. Technology and skill may thus not always be complements, as we have seen for the automobiles example above. In addition, the measure of technological change in the previous chapter was not corrected for the change in labor quality. Consequently, labor quality is actually a part of technological change making a direct comparison between both measures hazardous.

5.6 Conclusion

In this chapter I compiled new measures of labor-quality change in the United States for the 1900–1950 period. In contrast to previous studies, my estimates include a detailed sectoral breakdown, allowing me to study both the development of labor quality for the entire US labor force as well as the change across different sectors and industries. For my time-series estimation, I follow the approach advocated by Jorgenson et al.; a method also currently in use by the American Bureau of Labor Statistics.

The measurement of labor quality, or labor services, is of particular importance to the study of productivity and technological change. Within a growth accounting framework, the rate of growth of total factor productivity is defined as the difference between the rate of growth of real product and the rate of growth of real factor inputs.[87] The labor quality adjustment, presented in this chapter, provides a more extensive measure of labor input which will in turn allow for a purer measure of technical change. The results presented in this chapter allow, for the first time, for such a quality adjustment of labor in all the major sectors of the American economy during the first half of the twentieth century.

Overall, I find that labor quality exhibited a steady increase during the first half of the twentieth century. The average growth rate between 1900 and 1950 was approximately 0.72 percent per annum, in accordance with the continuous increase in the average years of schooling as outlined by Goldin and Katz.[88] At the sectoral level, labor-quality change was more pronounced in agriculture and industry than it was for services. My disaggregate results show that the fastest rate of labor-quality growth occurred in the mining, manufacturing and personal and professional service sectors, while wholesale trade, FIRE and public administration exhibited slow progress. The

87. Jorgenson and Griliches, "The Explanation of Productivity Change," 249.
88. Goldin and Katz, *The Race Between Education and Technology*.

sectoral decomposition shows annual rates of growth ranging from -0.18 to 0.60 percent.

Given the paucity of data on particularly educational attainment and labor compensation, prior to 1940, I have made a number of assumptions that may bear upon my final estimates. The pre-1940 labor quality estimates are based on predicted values of educational attainment, where I implicitly assume a stable relationship between occupations and education attainment as well as a log-linear relation between birth cohorts and education. In addition, for the compensation weights I rely exclusively on wage and income data taken from the 1940 and 1950 census returns, thus assuming that no notable changes in the relative wage structure occurred during the course of the early twentieth century. Finally, I made no attempt to compensate for differences in hours worked between the labor categories distinguished in this study. It is very likely, however, that some groups (e.g. women) worked considerably shorter hours, which is likely to have affected their average wage and thus their implied contribution to labor input.

In various parts of this chapter I discussed a number of these assumptions, endeavoring to establish their validity.[89] Still, future work could benefit from particularly the estimation of pre-1940 labor-compensation and hours figures, cross-classified by the categories that make-up labor input; i.e. educational attainment, gender, age or experience and industry. As established by Goldin and Katz, however, this will present a considerable challenge as this data is lacking entirely from the early twentieth century population censuses, and only fragmentary data on a select few regions and time-periods can be found elsewhere. The evidence that is available suggest, however, that the wage structure observed in 1940 was fairly typical for the prewar period, lending credence to the estimates presented here.[90] Given the broad agreement between my labor quality estimates for the total economy and the well-established estimates by Denison, I feel confident that the new sectoral figures provide a valuable addition to the American productivity debate.[91]

89. See for instance appendix 5.A for a discussion on the assumptions behind the logistic regression, or section 5.5 for a discourse on the wages for female workers .

90. Goldin and Katz, *The Race Between Education and Technology*, 53–7, 59–63.

91. Denison and Poullier, *Why Growth Rates Differ*, 85; Gordon, "US Economic Growth Since 1870: One Big Wave?," 124.

5.A Estimation of educational attainment

Table 5.8 reports the main results for the logistic regression. For the analysis of labor quality I start with a basic model where educational attainment is estimated solely on the basis of occupational characteristics, gender and birth cohorts. Subsequently, I extend this model to include regional dummies, controls for young workers as well as interaction effects between the educational categories and the predictor variables. Overall, with the exception of the controls for young workers, all variables are highly significant and show the predicted sign. The inclusion of interaction effects – i.e. separate beta-coefficient for each of the educational response categories – reveal significantly different coefficients between the educational categories for most of the included predictor variables. For the estimation of educational attainment I always include a set of dummy variables for the occupational categories and gender as well as the natural log of the birth cohort variable.[92]

By taking the natural log of the birth-cohort variable instead of incorporating a full set of dummies for the birth cohorts, I assume a log-linear relationship between birth cohorts and educational attainment. This assumptions allows me to reliably predict the educational attainment of individuals born as early as 1820. Figure 5.6 illustrates the validity of this assumption and, in addition, a number of plausible alternatives. All panels in figure 5.6 present the probability that a male employee, engaged as clerical staff, has only attended grade school and did not continue on to high school or college. The upper-left panel (a) shows the predictions from a logistic regression based on a full set of cohort dummies, which covers the period from 1840 to 1920. For the labor quality estimation in 1900 I also require data on individuals born prior to 1840, however. The upper-right panel (b) compares the fit from the predictions based on the natural log of the birth cohort variable to those in panel (a). This shows that the fit from the log-linear extrapolation is actually very close to the predictions based on the cohort dummies. In addition, panel (b) provides the probabilities for the 1820 and 1830 cohorts, which appear to fit in nicely with the trend observed for later cohorts.[93] For other combinations of occupations, gender and educational categories I observe a

92. I exclude the tenth occupational category (laborers) from the set of dummies as it represents my reference category. The eleventh occupational category ‘unemployed/retired’ is included in the logistic regression, even though this category is subsequently dropped when I predict the educational attainment of the workforce. Nonetheless, as observations from this category provide valuable data for the estimation of the parameters of the remaining variables (e.g. birth cohort and gender), I retained the eleventh category.

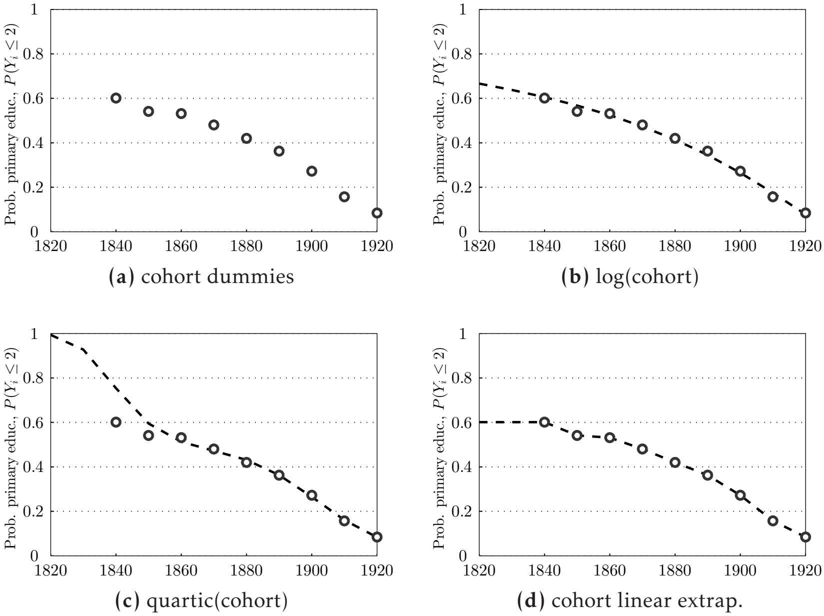
93. An alternative assumption is presented in panel (c), which shows the probabilities based on a quartic function of the birth cohort variable. For the cohorts born after 1860, this model again provides a very good fit compared to that presented in panel (a). Prior to 1860 however, the predictions based on the quartic for cohorts starts to deviate and the probabilities for the 1820 and 1830 cohorts do not appear to be very credible. Lastly, in panel (d), I take the results from panel (a) which I extrapolate on the assumption that the educational attainment between 1820 and 1840 remained unchanged. This prediction naturally results in a clear break in trend between the pre- and post-1840 periods.

Table 5.8: Logistic regression results, estimation of educational attainment

	Model I			*Model II*			*Model III*		
	$P(Y_i{=}1)$	$P(Y_i{\le}2)$	$P(Y_i{\le}3)$	$P(Y_i{=}1)$	$P(Y_i{\le}2)$	$P(Y_i{\le}3)$	$P(Y_i{=}1)$	$P(Y_i{\le}2)$	$P(Y_i{\le}3)$
(Intercept)	-2.04	0.48	3.02	-2.26	0.31	2.89	-2.49	0.32	3.86
	(0.007)*	(0.007)*	(0.008)*	(0.009)*	(0.009)*	(0.009)*	(0.014)*	(0.011)*	(0.028)*
occ. 1		-4.62			-4.57		-3.43	-4.00	-4.89
		(0.014)*			(0.014)*		(0.053)*	(0.021)*	(0.029)*
occ. 2		-0.46			-0.48		-0.68	-0.52	-0.76
		(0.011)*			(0.011)*		(0.015)*	(0.014)*	(0.036)*
occ. 3		-2.31			-2.25		-1.94	-2.25	-2.73
		(0.012)*			(0.012)*		(0.024)*	(0.014)*	(0.030)*
occ. 4		-2.42			-2.36		-3.12	-2.79	-2.73
		(0.011)*			(0.011)*		(0.044)*	(0.015)*	(0.029)*
occ. 5		-2.26			-2.20		-2.33	-2.41	-2.56
		(0.013)*			(0.013)*		(0.035)*	(0.016)*	(0.031)*
occ. 6		-1.23			-1.14		-1.47	-1.22	-1.13
		(0.010)*			(0.010)*		(0.018)*	(0.012)*	(0.033)*
occ. 7		-0.81			-0.75		-0.88	-0.79	-0.65
		(0.009)*			(0.009)*		(0.014)*	(0.011)*	(0.033)*
occ. 8		-0.31			-0.34		-0.22	-0.32	-0.51
		(0.015)*			(0.015)*		(0.022)*	(0.018)*	(0.053)*
occ. 9		-1.12			-1.05		-1.07	-1.15	-1.25
		(0.012)*			(0.012)*		(0.021)*	(0.014)*	(0.036)*
occ. 11		-1.13			-1.02		-0.73	-1.17	-1.71
		(0.008)*			(0.009)*		(0.012)*	(0.011)*	(0.028)*
female		-0.07			-0.11		-0.36	-0.15	0.22
		(0.005)*			(0.005)*		(0.009)*	(0.006)*	(0.009)*
log(cohort)		1.05			1.16		1.24	1.32	0.34
		(0.003)*			(0.004)*		(0.007)*	(0.004)*	(0.007)*
young					0.32		0.18	0.02	0.79
					(0.009)*		(0.019)*	(0.010)	(0.019)*
region south					0.42		0.92	0.30	-0.09
					(0.005)*		(0.009)*	(0.006)*	(0.010)*
region midwest					-0.20		-0.45	-0.15	-0.21
					(0.005)*		(0.010)*	(0.006)*	(0.010)*
region west					-0.56		-0.43	-0.64	-0.62
					(0.007)*		(0.014)*	(0.008)*	(0.012)*
LogLikelihood:		-1,023,374			-1,010,735			-982,163	
Pseudo R^2:		0.114			0.125			0.150	
Chi^2 v. constant:		263,236 ($p < 0.001$)			288,496 ($p < 0.001$)			345,640 ($p < 0.001$)	

N = 975,261. Standard errors in parentheses. Statistical significance: * $p < 0.01$

Figure 5.6: Predicted educational attainment by birth cohorts (1820–1920)[a]



(**a**) cohort dummies

(**b**) log(cohort)

(**c**) quartic(cohort)

(**d**) cohort linear extrap.

[a] The figures above estimate the probability, for each birth cohort between 1820 and 1920, that a male worker, engaged in a clerical occupation (occ. 4), has only attended primary school (educ. 1 or 2). The probabilities are predicted on the basis of the full model (III) presented in table 5.8, where the 'log(cohort)' variable is exchanged for either a full set of cohort dummies or a quartic of the cohorts. The fit resulting from the model with a full set of cohort dummies in panel (a) is compared to alternative models in panels (b) and (c). The last panel, (d), mirrors the fit of (a) extrapolated to 1820 on the assumption that the educational attainment between 1820 and 1840 remained unchanged.

similarly good fit between these two alternative specifications, justifying my choice for the inclusion of the natural log of the birth cohort in the logistic regression.

The first three columns in table 5.8 show the parameter estimates and standard errors for *Model I*, the basic specification for the logistic regression. Unfortunately, the interpretation of the beta-coefficients is not as straightforward as is the case for a standard linear regression. As noted in the main text, the parameter estimates for the logistic regression model are linear effects but on the scale of the log of the odds ratios. The exponents of the parameters therefore show the multiplicative effects on the odds.[94]

The parameter estimates for the occupational categories are all significant and in line with the probabilities shown in table 5.2 in the main text. All the occupational categories have a reduced odds ratio in comparison to the laborer reference class, but the categories normally associated with high-skilled labor (i.e. professionals [1], managers and officials [3], clerical staff [4] and sales workers [5]) returned the lowest coefficients. The estimate for the log of the birth cohort is also significant and quite large. For instance, the odds ratio for an individual to have attended only primary or secondary education is twice as large for the 1910 cohort as it was for the 1920 cohort; in comparison the 1890 cohort's odds ratio is over 4 times as large. This corresponds to Goldin and Katz's findings of a steadily increasing educational attainment for younger generations. The dummy for female citizens is also significant, but the estimated parameter is very small. For the basic model there does not appear to be a difference between men and women in terms of educational attainment, once I correct for occupational and age characteristics.

The last three rows of table 5.8 report the model's log-likelihood ratio and goodness-of-fit statistics. The chi-square statistic compares the deviance of the full model against a constant model, which for all three specifications provides strong evidence against the null-hypothesis of no discernible difference in fit. The reported pseudo R-square represents the adjusted-McFadden statistic which again compares the fit of the full model against the constant model. Consequently, in contrast to the R-squared statistic for simple linear regressions, the logistic version does not represent a direct comparison of the observed versus the predicted values of the model and is therefore intuitively not as appealing. Nonetheless, I chose to report the pseudo R-square as this statistic proves to be a helpful tool in assessing the relative fit of my

94. To illustrate the interpretation of the parameter estimates, I will first estimate the cumulative probabilities for the reference category and subsequently analyze the effects the variables have on this probability. The reference category for the basic model is a male laborer (occ. 10) from the first birth cohort (1920). The log odds for the reference category are represented by the intercept, which is 0.48 for the second educational class (5–8 years grade school). This value yields an odds ratio of 1.63 which translates to a cumulative probability of 62 percent that an individual belonging to this reference category has only attended primary education. The cumulative odds ratio for the third educational class (high school) are much higher; the third intercept of 3.02 returns a cumulative probability of 95 percent. From these results the probabilities for the individual educational categories can easily be deduced. The probability an individual has attended college for example is equal to 1 minus the cumulative probability for the third educational category, i.e. 5 percent for my reference category. To estimate the cumulative probability for an individual engaged as manager instead of as a laborer I multiply the reference odds by the exponent of the 'occ. 3' parameter value. For the second educational class this would result in an odds ratio of $e^{0.48} \cdot e^{-2.31}$, or approximately 0.16, which translates to a probability of 14 percent. As expected, the probability for a manager to be educated beyond the primary level is substantially greater that it is for a common laborer. This example shows that a negative parameter estimate will lower the expected odds ratio, while a positive parameter will raise it. A lower odds ratio will in turn also produce a smaller cumulative probability value.

three competing specifications.[95]

Even though the basic model provides a good fit, there are still a number of concerns that need to be addressed. First of all the model predicts a very high share of young individuals in the higher educational categories, which is the result of the log-linear relationship assumed between the birth cohorts and the logit probability. In reality it would have been implausible, however, for someone aged 16 to have attended college. In *Model II* I take this constraint into account by adding a dummy for young workers.[96] In addition, I include the region variable described in section 5.3.

The results from the second model, listed in the fourth, fifth and sixth columns of table 5.8, show that the young workers do indeed have a higher probability of having only attended primary or secondary education. In addition, the parameter estimates for the regional dummies confirm the conclusions by Goldin and Katz. The educational attainment of individuals in the Western states is significantly higher than for individuals in the other States. Overall, the South reports the highest parameter estimate. The parameters for the variables included in the first model are only marginally affected by the addition of the new predictors. The only notable exception is the parameter estimate for birth cohort which has risen, reflecting the inclusion of the dummy for the young workers.

The previous two specifications both assume that the effect of the variables on the odds ratios is identical for all educational categories. For some of the parameters this may not be the case, however. To test this assumption, I include interactions between all variables and the educational categories in *Model III*. The coefficients in the last three columns in table 5.8 reveal a number of notable disparities between the estimates for the three cumulative educational categories. First, the right-most parameter for the gender-dummy shows a different sign. This demonstrates that for a given occupation, region and birth cohort the probability for women to have spent a year or more in high school is greater than it is for men. Reversely, the probability for them to have also attended college is actually lower. Second, turning to birth cohorts, I estimate a substantially higher parameter estimate for the first two (primary) educational categories. This suggests that the rise between generations in the number of individuals having attended some form of secondary education was much faster than it was for the shift between secondary and college education. This underscores the great leaps made during the early twentieth century toward mass secondary schooling, but also confirms that the greatest gains for college attendance occurred only later in the century. Third, the 'young' coefficients diverge considerably as well. The young-dummies

95. J. Gill, *Generalized Linear Models: A Unified Approach*, Sage University Papers Series on Quantitative Applications in the Social Sciences, 07-134 (Thousand Oaks: Sage, 2000).

96. A young workers in defined as an individual 22 years of age or younger who is part of the labor force, working either full- or part-time.

for the lowest educational classes are small or insignificant, while for the third educational category the estimate is quite large and significant. This shows that, for young-workers, only the probability to have attended college is reduced. Lastly, the new parameters for some occupational categories show a clear bias toward the highest educational category. This is particularly evident for professional and technical workers (occ. 1) who, in comparison to the reference category, are 50 times less likely to have only attended primary education but over 125 times more likely to have attended college or university.[97]

The discussion above suggests that there is strong evidence that the effect of the variables on the odds ratios differ between the educational categories. This is also reflected in the goodness-of-fit statistics, which show marked improvement between the second and last model specifications. The pseudo R-square, which offers the most intuitive interpretation of the model's relative fit, increased from 12.5 percent for *Model II* to 15.0 percent for *Model III*. Throughout this chapter I relied on the third model specification for my estimates of the pre-1940 educational attainment of the workforce.

97. Note that the odds ratio for the fourth educational category is the inverse of the cumulative odds ratio for the third educational category.

5.B Labor compensation

Table 5.9: Labor compensation ($, 1940)[a]

sex	*male*																			
educ.	*1–4 years grade school*					*5–8 years grade school*					*1–4 years high school*					*1 or more years college*				
age	*16-17*	*18-24*	*25-34*	*35-44*	*45+*	*16-17*	*18-24*	*25-34*	*35-44*	*45+*	*16-17*	*18-24*	*25-34*	*35-44*	*45+*	*16-17*	*18-24*	*25-34*	*35-44*	*45+*
A	173	270	397	509	558	266	413	679	824	866	323	517	830	1,056	1,135	...	912	1,484	1,758	1,881
B	378	683	952	1,248	1,291	604	955	1,361	1,701	1,759	695	1,147	1,607	1,989	2,206	...	1,631	2,288	2,865	2,996
C	327	566	844	1,071	1,216	544	828	1,268	1,548	1,627	606	988	1,482	1,848	1,973	...	1,467	2,153	2,647	2,800
20	501	640	947	1,206	1,357	568	859	1,311	1,614	1,742	830	987	1,503	1,906	2,103	...	1,347	2,111	2,600	2,896
21	266	592	789	935	1,106	358	739	1,025	1,271	1,467	469	900	1,304	1,743	2,061	...	1,350	1,918	2,729	3,125
22	403	532	715	908	968	490	714	999	1,257	1,385	574	839	1,188	1,568	1,758	...	1,244	1,813	2,467	2,685
23	375	627	1,027	1,256	1,383	502	786	1,230	1,558	1,676	607	881	1,410	1,818	1,990	...	1,229	2,032	2,539	2,610
24	309	400	606	738	856	442	619	939	1,152	1,288	447	805	1,162	1,534	1,644	...	1,154	1,805	2,237	2,494
25	273	569	801	1,005	1,119	374	777	1,125	1,384	1,470	583	895	1,325	1,663	1,844	...	1,189	1,805	2,439	2,551
26	313	637	879	1,145	1,190	507	857	1,231	1,556	1,628	592	995	1,419	1,860	1,993	...	1,462	2,093	2,708	3,028
27	362	769	1,188	1,785	1,705	477	987	1,663	2,148	2,269	518	1,069	1,789	2,307	2,511	...	1,499	2,466	3,241	3,518
28	357	599	932	1,207	1,341	464	916	1,440	1,733	1,829	730	1,075	1,654	2,131	2,327	...	1,547	2,448	3,233	3,426
29	415	771	1,199	1,564	1,622	556	1,029	1,628	1,984	2,069	652	1,210	1,842	2,287	2,485	...	1,663	2,549	3,190	3,403
30	448	659	983	1,324	1,358	648	966	1,429	1,800	1,807	866	1,118	1,639	2,084	2,306	...	1,663	2,447	3,129	3,217
31	342	586	959	1,174	1,250	483	768	1,159	1,437	1,583	597	878	1,324	1,769	1,951	...	1,275	2,064	2,856	3,063
32	346	642	879	1,174	1,196	505	893	1,297	1,602	1,679	632	1,006	1,477	1,913	2,075	...	1,579	2,161	3,166	3,294
33	318	781	1,017	1,311	1,384	447	959	1,408	1,738	1,825	512	1,086	1,588	2,052	2,241	...	1,517	2,286	3,041	3,196
34	345	680	1,042	1,268	1,376	475	930	1,355	1,693	1,849	556	1,038	1,554	2,027	2,216	...	1,409	2,370	2,877	3,169
35	486	589	1,035	1,327	1,432	1,033	966	1,478	1,809	1,914	812	1,114	1,650	2,120	2,281	...	1,509	2,291	3,069	3,250
36	286	777	1,137	1,481	1,558	584	977	1,488	1,926	2,006	478	1,109	1,663	2,206	2,395	...	1,582	2,465	3,358	3,539
37	630	851	1,162	1,464	1,546	892	1,057	1,555	1,910	2,013	1,067	1,164	1,705	2,182	2,325	...	1,577	2,379	3,065	3,120
38	360	668	1,076	1,289	1,506	554	950	1,475	1,712	2,015	538	1,071	1,539	1,939	2,252	...	1,407	2,294	2,830	3,324
39	336	682	949	1,165	1,268	519	845	1,293	1,626	1,703	644	959	1,485	1,890	2,060	...	1,334	2,091	2,910	2,923
E	630	643	970	1,252	1,401	585	938	1,455	1,801	1,956	688	1,087	1,655	2,110	2,331	...	1,440	2,258	2,911	3,130
F	302	660	982	1,237	1,414	470	937	1,466	1,871	2,024	544	1,099	1,695	2,256	2,454	...	1,502	2,361	3,100	3,335
G	294	532	835	1,084	1,161	433	749	1,181	1,485	1,542	460	861	1,336	1,721	1,804	...	1,210	1,884	2,422	2,455
H	355	697	1,005	1,256	1,375	515	955	1,540	1,897	2,009	683	1,132	1,823	2,350	2,600	...	1,539	2,541	3,331	3,581
I	292	435	686	875	961	386	635	1,049	1,315	1,360	474	785	1,263	1,598	1,663	...	1,218	1,973	2,560	2,650
J	632	579	1,066	1,323	1,447	526	799	1,495	1,906	2,015	688	963	1,680	2,147	2,333	...	1,415	2,340	2,996	3,256

continued on next page…

Table 5.9: Labor compensation (1940) – continued

sex	*female*																			
educ.	*1–4 years grade school*					*5–8 years grade school*					*1–4 years high school*					*1 or more years college*				
age	*16-17*	*18-24*	*25-34*	*35-44*	*45+*	*16-17*	*18-24*	*25-34*	*35-44*	*45+*	*16-17*	*18-24*	*25-34*	*35-44*	*45+*	*16-17*	*18-24*	*25-34*	*35-44*	*45+*
A	120	187	255	307	354	175	296	448	518	577	215	379	565	688	768	...	628	962	1,106	1,262
B	271	461	577	737	825	359	649	816	988	1,131	469	849	1,083	1,302	1,539	...	1,126	1,426	1,745	2,053
C	288	403	554	686	742	398	609	846	1,014	1,023	436	726	997	1,214	1,232	...	1,010	1,362	1,651	1,709
20	348	410	548	662	746	373	571	777	906	983	540	678	928	1,112	1,217	...	901	1,255	1,473	1,683
21	197	379	461	496	559	237	488	599	671	739	305	584	755	919	1,039	...	827	1,041	1,389	1,556
22	313	380	490	568	592	355	489	629	719	774	414	574	752	900	981	...	834	1,119	1,401	1,516
23	280	368	538	613	680	330	471	640	747	806	401	546	761	906	989	...	737	1,056	1,219	1,284
24	237	333	458	524	563	285	489	665	761	799	325	633	838	1,029	1,039	...	855	1,208	1,416	1,519
25	384	441	618	708	797	415	542	752	831	910	471	612	865	972	1,099	...	774	1,114	1,340	1,481
26	384	428	575	694	735	445	557	751	876	943	518	656	886	1,068	1,161	...	916	1,233	1,488	1,739
27	399	601	854	1,172	1,154	351	658	970	1,156	1,249	400	753	1,103	1,304	1,435	...	1,023	1,473	1,787	2,028
28	381	418	592	718	792	388	632	888	1,010	1,067	553	746	1,030	1,246	1,345	...	1,022	1,451	1,821	1,972
29	336	505	707	878	921	415	740	1,058	1,251	1,322	503	884	1,241	1,485	1,607	...	1,145	1,599	1,944	2,135
30	301	436	588	747	762	333	610	834	984	992	494	714	974	1,162	1,271	...	968	1,325	1,603	1,696
31	254	400	607	697	724	300	507	688	796	850	374	591	807	1,000	1,066	...	762	1,104	1,447	1,545
32	256	417	545	680	693	316	598	822	950	998	399	675	938	1,131	1,211	...	953	1,242	1,711	1,814
33	290	499	616	759	788	313	644	874	1,035	1,071	413	747	1,012	1,245	1,325	...	983	1,358	1,742	1,839
34	262	446	647	736	756	336	639	873	1,010	1,049	412	735	1,036	1,244	1,285	...	973	1,512	1,719	1,839
35	241	352	556	668	720	618	659	917	1,057	1,121	450	773	1,052	1,264	1,346	...	983	1,362	1,718	1,864
36	429	502	682	818	849	575	648	890	1,051	1,087	549	745	1,017	1,226	1,307	...	1,013	1,430	1,792	1,915
37	330	599	763	942	979	389	721	952	1,144	1,189	523	829	1,093	1,355	1,409	...	1,070	1,431	1,812	1,863
38	323	468	660	748	832	391	616	867	945	1,063	468	742	985	1,162	1,273	...	931	1,364	1,584	1,819
39	304	429	556	627	696	394	553	760	880	945	486	655	914	1,067	1,178	...	857	1,201	1,551	1,627
E	469	459	652	800	852	417	653	938	1,107	1,152	490	754	1,067	1,287	1,349	...	948	1,371	1,685	1,772
F	371	442	598	714	783	445	639	884	1,069	1,119	512	754	1,041	1,308	1,364	...	1,001	1,396	1,746	1,861
G	240	361	518	636	684	310	493	692	822	860	339	576	799	970	1,013	...	783	1,086	1,328	1,385
H	370	481	635	738	785	420	647	911	1,047	1,083	532	762	1,080	1,299	1,394	...	995	1,435	1,767	1,906
I	172	235	337	398	435	212	361	536	625	639	280	483	710	842	859	...	736	1,101	1,363	1,426
J	424	491	746	882	949	324	651	977	1,172	1,232	433	798	1,144	1,374	1,464	...	1,111	1,518	1,839	2,022

[a] For industry descriptions and an overview of the education, age and sex characteristics see table 5.1.

5.C Growth decomposition of labor quality

Table 5.10: Labor-quality growth decomposition, main sectors (ln%, 1900–1950)[a]

		first order				*second order*						*third order*				*fourth order*
	total	*e*	*a*	*s*	*i*	*ea*	*es*	*as*	*ei*	*ai*	*si*	*eas*	*eai*	*esi*	*asi*	*easi*
A	25.9	17.0	8.4	-0.6	...	1.7	-0.3	-0.3	...	...	...	0.0	...	...	...	...
B	22.0	11.5	7.7	-0.9	...	3.3	0.0	0.2	...	...	...	0.1	...	...	...	...
C	13.0	8.6	2.5	-0.7	...	2.3	0.1	0.1	...	...	...	0.0	...	...	...	...
D	25.8	10.9	12.4	-5.9	7.8	4.6	1.4	-1.8	-2.2	-1.0	-0.4	-0.9	-0.5	-0.1	1.3	0.2
E	16.9	7.3	8.9	-6.0	...	4.7	1.5	1.6	...	...	...	-1.3	...	...	...	...
F	2.0	5.4	0.6	-9.3	...	3.1	0.8	1.9	...	...	...	-0.5	...	...	...	...
G	4.2	4.4	7.7	-12.5	...	3.8	1.4	0.0	...	...	...	-0.6	...	...	...	...
H	-8.0	6.0	-5.4	-17.5	...	3.7	1.8	4.4	...	...	...	-1.0	...	...	...	...
I	26.2	15.5	13.7	3.9	...	1.2	-4.2	-5.3	...	...	...	1.3	...	...	...	...
J	-5.1	6.1	-10.5	-4.2	...	3.2	0.8	-0.3	...	...	...	-0.3	...	...	...	...
TOT	35.8	17.6	7.7	-6.4	20.4	3.5	1.5	-0.7	-7.8	0.2	1.7	-0.9	-0.4	-1.3	0.1	0.6

[a] For industry descriptions and an overview of the education, age and sex characteristics see table 5.1; 'TOT' represents the total economy. The second, third and fourth order terms are residual effects from which the relevant lower-order effects were subtracted. May not sum to total due to rounding.
Source: see text.

Table 5.11: Labor-quality growth decomposition, manufacturing industries (ln%, 1900–1950)[a]

		first order				*second order*						*third order*				*fourth order*
	total	*e*	*a*	*s*	*i*	*ea*	*es*	*as*	*ei*	*ai*	*si*	*eas*	*eai*	*esi*	*asi*	*easi*
20	11.3	8.5	6.6	-8.7	...	4.0	1.2	0.6	...	...	...	-0.8	...	...	...	...
21	14.8	9.8	20.2	-19.0	...	4.6	0.7	-1.8	...	...	...	0.4	...	...	...	...
22	29.6	8.6	19.8	1.4	...	4.0	1.4	-5.0	...	...	...	-0.6	...	...	...	...
23	11.7	5.7	22.3	-15.9	...	5.2	1.2	-6.0	...	...	...	-0.8	...	...	...	...
24	22.4	13.3	7.7	-1.0	...	2.3	0.2	0.1	...	...	...	-0.2	...	...	...	...
25	9.6	7.6	2.7	-5.5	...	3.7	0.6	1.1	...	...	...	-0.6	...	...	...	...
26	29.8	9.9	17.0	3.2	...	4.4	1.9	-5.7	...	...	...	-0.8	...	...	...	...
27	14.8	2.9	16.4	-7.0	...	3.3	1.3	-1.3	...	...	...	-0.7	...	...	...	...
28	23.3	14.5	9.1	-4.7	...	3.9	2.5	-0.7	...	...	...	-1.4	...	...	...	...
29	26.4	14.6	9.5	-4.3	...	4.9	1.2	0.9	...	...	...	-0.3	...	...	...	...
30	28.6	10.4	16.4	0.7	...	4.3	2.1	-4.9	...	...	...	-0.5	...	...	...	...
31	0.1	4.9	4.2	-15.8	...	4.6	1.7	1.8	...	...	...	-1.2	...	...	...	...
32	16.8	10.4	8.7	-6.5	...	3.2	0.9	1.0	...	...	...	-0.8	...	...	...	...
33	21.8	8.3	11.1	-2.5	...	4.3	0.5	0.4	...	...	...	-0.3	...	...	...	...
34	19.7	8.2	11.9	-7.4	...	5.0	1.6	1.1	...	...	...	-0.8	...	...	...	...
35	18.6	8.0	11.0	-5.8	...	4.2	1.0	0.8	...	...	...	-0.6	...	...	...	...
36	24.9	8.4	22.7	-9.3	...	3.8	2.1	-2.2	...	...	...	-0.7	...	...	...	...
37	12.0	8.8	2.9	-4.9	...	3.9	1.0	0.8	...	...	...	-0.5	...	...	...	...
38	21.8	6.6	19.5	-7.0	...	3.4	2.4	-1.8	...	...	...	-1.2	...	...	...	...
39	19.5	10.7	14.0	-9.5	...	5.2	2.3	-1.9	...	...	...	-1.2	...	...	...	...
D	25.8	10.9	12.4	-5.9	7.8	4.6	1.4	-1.8	-2.2	-1.0	-0.4	-0.9	-0.5	-0.1	1.3	0.2

[a] For industry descriptions and an overview of the education, age and sex characteristics see table 5.1; 'D' represents total manufacturing. The second, third and fourth order terms are residual effects from which the relevant lower-order effects were subtracted. May not sum to total due to rounding.

Source: see text.

5.D Level decomposition of labor quality

Table 5.12: Labor quality level decomposition, main sectors (TOT=100, 1900–1950)[a]

char.	*education · age · sex*						*education*						*age*						*sex*					
year	*1900*	*1910*	*1920*	*1930*	*1940*	*1950*	*1900*	*1910*	*1920*	*1930*	*1940*	*1950*	*1900*	*1910*	*1920*	*1930*	*1940*	*1950*	*1900*	*1910*	*1920*	*1930*	*1940*	*1950*
A	90	91	91	89	88	93	87	87	87	86	87	89	101	101	102	100	99	100	104	104	105	106	107	107
B	98	97	96	96	96	103	98	98	96	95	94	96	101	101	101	102	103	102	100	100	101	100	102	104
C	110	106	108	104	98	101	101	99	98	97	93	96	109	107	108	106	104	102	102	102	103	102	102	103
D	96	96	96	96	97	99	98	98	98	98	98	97	95	95	96	97	98	101	101	102	101	101	100	101
E	105	104	103	105	110	105	100	100	100	99	99	98	102	100	99	101	105	101	105	107	105	105	106	106
F	130	125	118	116	114	109	114	111	108	106	105	102	109	106	103	103	102	101	106	107	105	104	104	104
G	113	110	107	105	99	96	111	108	106	105	101	99	99	99	100	99	98	99	101	99	97	98	97	96
H	132	124	112	109	115	104	115	112	109	107	110	106	114	106	100	100	104	100	103	104	97	97	97	94
I	93	92	95	94	95	96	122	115	115	112	112	109	95	100	100	99	99	101	75	77	81	83	84	88
J	125	122	109	115	114	102	110	108	105	104	108	103	110	108	99	106	101	94	105	106	104	104	102	104
TOT	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

[a] For industry descriptions and an overview of the education, age and sex characteristics see table 5.1; 'TOT' represents the total economy.

Source: see text.

Table 5.13: Labor quality level decomposition, manufacturing industries (D=100, 1900–1950)[a]

char.	*education · age · sex*						*education*						*age*						*sex*					
year	*1900*	*1910*	*1920*	*1930*	*1940*	*1950*	*1900*	*1910*	*1920*	*1930*	*1940*	*1950*	*1900*	*1910*	*1920*	*1930*	*1940*	*1950*	*1900*	*1910*	*1920*	*1930*	*1940*	*1950*
20	109	108	104	101	102	100	101	101	101	101	100	100	105	105	102	100	99	100	104	104	101	101	102	100
21	92	88	85	82	82	85	99	98	97	97	94	93	96	97	99	97	101	103	93	87	84	83	84	87
22	81	84	84	84	85	87	98	98	97	97	95	94	90	93	94	94	97	100	87	88	89	90	92	93
23	80	81	82	81	76	78	100	100	100	99	96	95	91	90	95	96	98	100	81	81	80	80	77	79
24	101	100	101	100	97	96	95	95	94	94	94	93	105	104	104	103	100	100	105	105	106	106	107	106
25	113	108	109	106	103	99	101	100	100	99	98	98	108	105	106	104	100	98	106	105	104	105	106	104
26	89	96	97	100	101	99	99	99	99	100	101	100	93	99	99	101	100	98	92	97	98	100	100	100
27	108	107	106	104	108	104	111	109	106	106	104	106	97	98	99	97	99	98	101	98	98	99	101	99
28	105	103	103	102	106	108	101	100	101	102	104	105	103	102	101	100	100	100	102	102	102	101	102	102
29	107	109	108	107	119	122	99	100	102	103	106	108	104	105	103	102	105	101	104	105	105	106	107	106
30	92	95	98	98	106	104	100	101	101	101	103	102	95	96	97	97	100	99	93	96	101	99	101	100
31	106	96	95	91	90	88	99	99	99	98	98	95	107	100	99	97	98	99	102	97	96	95	92	93
32	105	105	104	105	105	102	99	98	98	98	99	99	103	104	104	104	102	100	106	106	105	106	105	104
33	104	104	106	108	107	106	99	99	99	99	99	97	104	103	104	105	103	102	105	105	106	106	107	107
34	106	105	105	106	105	104	101	100	101	100	102	101	102	101	101	103	101	100	106	105	104	104	103	103
35	106	107	107	111	113	108	102	102	102	102	103	101	102	101	101	105	103	101	105	106	106	106	107	105
36	91	99	98	98	103	99	102	104	104	104	104	103	89	94	94	93	97	99	98	101	99	99	98	95
37	110	107	105	107	109	107	99	101	101	100	101	101	110	104	100	102	103	101	105	105	106	106	107	106
38	95	93	93	98	104	103	102	103	103	103	105	103	93	92	92	96	98	99	98	93	94	97	97	97
39	95	98	97	97	96	96	99	100	100	100	101	101	97	98	99	98	97	99	97	98	97	97	96	95
D	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

[a] For industry descriptions and an overview of the education, age and sex characteristics see table 5.1; 'D' represents total manufacturing.
Source: see text.

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Nederlandse Samenvatting

De jaren dertig van de vorige eeuw worden zelden gezien als een tijd van technologische en organisatorische vernieuwing, laat staan als een periode van snelle arbeidsproductiviteitsgroei. In plaats daarvan wordt dit decennium vaak geassocieerd met langdurige werkloosheid, mislukte oogsten, faillissementen, inkomensteruggang en algehele financiële malaise, zeker als men terugdenkt aan de economische situatie in de Verenigde Staten. Tijdgenoten dachten daar niet anders over. In de vroege jaren veertig bestempelde het tijdschrift *Life* het voorgaande decennium als de "Gloomy Thirties" (Sombere Jaren Dertig), terwijl *Time* opteerde voor het al even grimmige "Threadbare Thirties" (Armzalige Jaren Dertig).

De wetenschappelijke literatuur legt eveneens de nadruk op de negatieve gevolgen van de crisis die de Amerikaanse aandelenbeurs verlamde in de herfst van 1929, en de 'Grote Depressie' die daarop volgde. Het overgrote deel van deze studies, zowel in de economie als in de economische geschiedenis, richt zich op de beurskrach, de *run* op de spaarbanken en de internationale monetaire crisis. De meeste evalueren de directe gevolgen op de consumentenbestedingen, de werkgelegenheid, het prijsniveau, de internationale handel en de reële productie. Daarnaast kijken verschillende studies terug op het fiscale en monetaire beleid gevoerd onder het presidentschap van zowel Hoover als Roosevelt en de lessen die daar, in het licht van de recente financiële crisis, uit zijn op te maken.

Waar de meeste van deze academische bijdragen zich richten op de productiemiddelen die niet benut werden en de inkomsten die uitbleven, stelt de economisch historicus Alexander Field dat voor de VS de jaren dertig, paradoxaal genoeg, ook de technologisch meest vooruitstrevende periode van de vorige eeuw vertegenwoordigen. De hypothese van Field bouwt voort op eerder werk van Michael Bernstein en Ester Fano en omvat twee stellingen: (1) gedurende de jaren dertig werd door bedrijven en de overheid een breed aanbod van nieuwe technologieën en organisatorische veranderingen geïntroduceerd, wat resulteerde in de sterkste trendgroei van totale factorproductiviteit in de twintigste eeuw, en (2) de depressie bracht een groot aantal innovaties voort die de voorraad onbenutte of slechts gedeeltelijk benutte technieken aanvulde en uitbreidde, welk op hun beurt de basis vormden voor veel van de arbeids- en totale factorproductiviteitsverbetering van de jaren vijftig en zestig.

Field betoogt dat de periode 1929–1941 weinig tot geen groei liet zien in zowel het totale aantal gewerkte uren, als in de kapitaalvoorraad. Desalniettemin groeide de productie in de Amerikaanse private sector (exclusief de agrarische sector), gedurende deze twaalf jaar, met naar schatting ergens tussen de 33 tot 40 procent. De kloof tussen de groei van productie en productiemiddelen weerspiegelde, zo stelt Field, de verbetering in de totale factorproductiviteit, welke resulteerde in een reële vergroting van de productiecapaciteit van de Amerikaanse economie met maar liefst 2,3 tot 2,8 procent per jaar. De technologische winst die werd geboekt gedurende de jaren dertig was groter dan de stijging van de reële productie per werknemer in de jaren twintig en oversteeg zelfs de winst geboekt tijdens de 'Gouden Jaren', de kwart eeuw tussen 1948 en 1973.

Voor specifieke voorbeelden van de technologische veranderingen in de jaren dertig wendt Field zich tot een studie van David Weintraub. Weintraub beschrijft onder andere de ontwikkeling van het chroomproces en corrosie-bestendige staallegeringen en verbeteringen in verven, vernissen en lakken. Hij toonde aan dat, door de ontwikkeling van cellulose-lakken de tijd die nodig was voor de productie van een auto (door het verminderen van de droogtijd) werd verkort van 26 dagen tot slechts een paar uur. Verdere verbeteringen in chemische processen resulteerden in hogere opbrengsten in de commerciële winning van ertsen en nieuwe toepassingen voor afvalproducten, voornamelijk in de aardolie- en aardgasindustrie.

Daarnaast lieten de jaren dertig een stijging zien in het gebruik van machines en apparatuur met een verhoogde capaciteit, wat eveneens de arbeids- en kapitaalproductiviteit sterk stimuleerde. Dit was zichtbaar voor apparatuur in algemeen gebruik, zoals industriële locomotieven, shovels en elektrische motoren, maar ook in vaste installaties, zoals cementovens, moleninstallaties in de mijnbouw, transportbanden in meelfabrieken en generatoren. Het gebruik van grotere ketels door elektriciteitsbedrijven resulteerde in een aanzienlijk hoger thermisch rendement en een bijna ononderbroken stijging van de energieproductie gedurende de jaren twintig en dertig. Gerelateerd aan deze voortdurende trend naar grotere productie-eenheden was het groeiend belang van industriële meet- en regelapparatuur. Deze verbeteringen vergemakkelijkten de automatisering van controleprocessen, verminderden de stilstand en onderhoudskosten van machines en verlengden de levensduur van de productieapparatuur aanzienlijk.

De depressiejaren werden tevens gekenmerkt door de introductie van nieuwe en verbeterde materialen en onderdelen. Naast de eerder genoemde staallegeringen werden in toenemende mate houten of metalen onderdelen vervangen door kunststoffen, werden nieuwe materialen voor snijgereedschappen geïntroduceerd (bijv. wolfraamcarbide) en werden verouderde glijlagers door rollagers vervangen. Ten slotte introduceerden producenten gedurende de jaren dertig continue verbeteringen in het ontwerp en de inrichting van fabrieken door middel van onder andere de installatie van transportbanden en de implementatie van massaproductiemethoden. Hoewel de basis voor veel van deze ontwikkelingen al in de jaren twintig was gelegd, waren er nog steeds aanzienlijke winsten te behalen in het depressietijdperk.

De claim van Field, dat de periode tussen 1929 en 1941 inderdaad een technisch zeer vooruitstrevend decennium was, roept nog wel een aantal vragen op. Field speculeert dat de productiviteitskloof tussen Europa en de VS verder opliep gedurende de jaren dertig, maar hij presenteert geen concreet bewijs hiervoor. Zijn relaas richt zich vrijwel volledig op de Amerikaanse ervaring, wat dientengevolge de vraag oproept of deze snelle technologische ontwikkelingen uniek waren voor de VS of dat soortgelijke ontwikkelingen ook zichtbaar waren in Europa. Daarnaast negeert Field de rol van menselijk kapitaal. Zoals Claudia Goldin en Lawrence Katz illustreerden, onderging de Amerikaanse beroepsbevolking een ongekende stijging in het opleidingsniveau gedurende de late negentiende en vroege twintigste eeuw, een trend die niet werd doorbroken tijdens de depressie. Verrassend genoeg beweert Field echter dat de verbeteringen in het onderwijs en de daaruit voortvloeiende groei van de kwaliteit van arbeid geen effect hadden op de groei van de arbeids- of totale factorproductiviteit. Dit effect werd, zo stelt hij, gedurende de hele periode 1929–1941 overschaduwd door andere factoren.

De onderhavige studie werpt een nieuwe blik op de productiviteit in zowel de Verenigde Staten als het Verenigd Koninkrijk – de belangrijkste industriële rivaal van de VS. In het licht van de dynamische ontwikkeling van de productiviteit, beschreven door Field, analyseer ik opnieuw de Britse technologische en organisatorische innovaties van begin twintigste eeuw en bied ik een geheel nieuwe verklaring voor de snelle divergentie van de Anglo-Amerikaanse arbeidsproductiviteitsniveaus. Hoofdstukken 2 en 3 presenteren twee nieuwe *benchmark* vergelijkingen, of ijkpunten van de Anglo-Amerikaanse comparatieve arbeidsproductiviteit. Hiermee leg ik de relatieve verhoudingen tussen de twee belangrijkste industriële naties bloot, zowel tijdens het begin van de twintigste eeuw (ca. 1910) als het interbellum (1935). Hoofdstuk 4 gaat in op de technologische verandering, kapitaalaccumulatie en efficiëntie van de industriële productie van Groot-Brittannië en de VS tussen de twee wereldoorlogen. Ten slotte, in hoofdstuk 5, kijk ik terug op de kwaliteit van arbeid in de Amerikaanse economie en de ontwikkeling daarvan gedurende de eerste helft van de twintigste eeuw.

Ik kom tot de conclusie dat aan de vooravond van de Eerste Wereldoorlog het gat tussen het bruto binnenlands product per hoofd van de bevolking en de arbeidsproductiviteit van de VS en het VK groter was dan tot nu toe werd gesteld. In hoofdstuk 2 laat ik zien dat vooral de Amerikaanse landbouw en industriële sectoren relatief productief waren in vergelijking met hun Britse tegenhangers. Rond 1910 lag de toegevoegde waarde per uur gewerkt, in de Amerikaanse industrie, iets meer dan een factor twee maal hoger dan in het VK. Ondanks deze ruime voorsprong vergrootte de Amerikaanse industrie de kloof in arbeidsproductiviteit nog verder gedurende de jaren twintig en dertig totdat deze, in 1935, was uitgegroeid tot bijna 280 procent. Opvallend genoeg vind ik dus geen enkele aanwijzing voor een 'tijdelijke conjuncturele convergentie' voorafgaand aan de Tweede Wereldoorlog, zoals wordt aangevoerd door de economisch historicus Stephen Broadberry. Integendeel, als arbeid gecorrigeerd wordt voor de terugval in het gemiddelde aantal gewerkte uren, laat de productiviteitskloof tussen beide landen een aanhoudende opwaartse trend zien gedurende de depressiejaren; zoals ik aantoon in hoofdstuk 3. De gestage divergentie van de Anglo-Amerikaanse arbeidsproductiviteitsniveaus lijkt Field's claims, van grote productiviteitsverbeteringen in de VS gedurende het tweede kwart van de twintigste eeuw, te onderschrijven.

De leiderschapsrol van Amerika wordt vaak toegeschreven aan de verschillen in initiële condities en relatieve factorprijzen tussen de VS en Europa. Waar Amerikaanse producenten al in de negentiende eeuw kozen voor voornamelijk kapitaalintensieve productiemethoden, opteerden producenten in Europa (waar arbeid relatief goedkoop was) juist voor een arbeidsintensief productieproces. Dit patroon in de verschillende keuzen van industriële technologieën in Groot-Brittannië en de Verenigde Staten werd volgens Broadberry voortgezet in de twintigste eeuw. Dit zou dan ook het gebrek aan convergentie in de productiviteitsniveaus tussen beide landen kunnen verklaren; Britse producenten bleven een arbeidsintensief productiesysteem nastreven wat, tot de jaren zeventig, minder effectief bleek dan het Amerikaanse systeem van massaproductie.

In hoofdstuk 4 analyseer ik opnieuw de productiviteit in de Britse industrie gedurende de vroege twintigste eeuw. Ik doe dit aan de hand van een nieuw analytisch kader, ontwikkeld door Susanto Basu en David Weil, dat de rol van leren en gelokaliseerde technologische verandering benadrukt en dat convergentie in het licht van snelle kapitaalvorming voorspelt. Met behulp van een *Data Envelopment Analysis* (DEA) kan ik de effecten van kapitaalaccumulatie, technologische ontwikkelingen en veranderingen in de efficiëntie op de Britse en Amerikaanse arbeidsproductiviteit kwantificeren.[1] Hier vind ik bewijs voor een aanzienlijke verhoging van de kapitaalintensiteitsniveaus binnen de Britse industrie – met name in de 'nieuwe' industrieën die nauw verbonden waren met de Tweede Industriële Revolutie – waaruit ik opmaak dat deze belangrijke industrieën actief op zoek waren naar moderne technieken van massaproductie en management. Hoewel rond 1930 de Britse industrie nog steeds ongeveer twee decennia achter lag op de Verenigde Staten in termen van kapitaalintensiteit, waren de grote verschillen tussen de *best-practice* productietechnieken rond die tijd al veelal verdwenen. De Britse producenten van auto's, bijvoorbeeld, volgden het pad van de Amerikaanse auto-industrie. Het interbellum toonde grote investeringsprogramma's, de geleidelijke invoering van gemechaniseerde productietechnieken, assemblagelijnen en gespecialiseerde machines en de opkomst van tal van nieuwe producten en processen in de Britse industrie.

Zoals blijkt uit de gestage divergentie van de Anglo-Amerikaanse arbeidsproductiviteit tijdens de vroeg twintigste eeuw, ging het proces van kapitaalaccumulatie en modernisering niet gepaard met een onmiddellijke toename van arbeidsproductiviteit in de Britse industrie. In tegenstelling tot de bestaande literatuur interpreteer ik het ontbreken van deze zogenaamde *catch-up* groei tijdens de jaren twintig en dertig echter niet als een tekortkoming aan de zijde van de Britse ondernemers. In plaats daarvan stel ik een reeks voor waarbij eerst kansen voor groei worden gecreëerd, gevolgd door een periode van *learning-by-doing* en ten slotte de daadwerkelijke convergentie van productiviteitsniveaus. De eerste fase van *catch-up*, de invoering van nieuwe productietechnieken middels de accumulatie van kapitaal, omvat een uitgebreide transformatie van het productieproces. Dit resulteert, op de korte termijn, in een daling van de efficiëntieniveaus en een stagnatie van de productiviteit. Pas nadat de economie een nieuw evenwicht heeft bereikt, en producenten 'geleerd' hebben het potentieel van de nieuwe technologieën volledig te benutten, vindt er convergentie in termen van arbeidsproductiviteit plaats. Vergelijkbaar met de claim van Field voor de VS, beargumenteer ik dat de technologische vooruitgang geboekt tijdens de depressiejaren de basis vormde voor de snelle arbeids- en totale factorproductiviteitsgroei van de Britse industrie tijdens de Gouden Jaren (1948–1973). Ik betoog echter wel dat, in het geval van Groot-Brittannië, het moderniseringsproces werd beperkt door institutionele belemmeringen, wat verklaart waarom de technologische diffusie niet zo wijdverspreid was en de technologische paden van de VS en het VK na de Tweede Wereldoorlog niet zo snel convergeerden als het geval was voor bijvoorbeeld West-Duitsland en Frank-

1. *Data Envelopment Analysis* is een non-parametrische methode die in de economische wetenschappen wordt gebruikt voor het schatten van zogenaamde 'productiemogelijkhedencurves'. Met behulp van deze curves is het mogelijk het maximaal haalbare productieniveau – gegeven een set van productiefactoren – uit te zetten tegenover de daadwerkelijk gerealiseerde productie. Hiermee kan de efficiëntie van productie worden vastgesteld.

rijk.

In hoofdstuk 5 richt ik mij op de Amerikaanse investering in onderwijs en het effect hiervan op de kwaliteit van arbeid en het productiviteitspotentieel van de beroepsbevolking. Zoals aangetoond door Goldin en Katz, koos men in de VS al vroeg voor een onderwijssysteem dat grotendeels werd bekostigd door de staat en dat toegang bood aan alle lagen van de samenleving. Het Amerikaanse onderwijsmodel stond hierbij in schril contrast met het Europese systeem dat begin twintigste eeuw nog steeds was voorbehouden aan de relatief rijken. De investering in het onderwijs, eind negentiende en begin twintigste eeuw, transformeerde de Amerikaanse beroepsbevolking en bereidde de Amerikaanse jeugd voor op een breed scala aan mogelijke taken en beroepen. Verscheidene auteurs hebben al aangetoond dat de Amerikaanse benadering van onderwijs een van de drijvende krachten was achter de technologische dynamiek die deze periode kenmerkte en de weg vrijmaakte voor snelle economische groei. Dit is in strijd met de bewering van Field die, zoals al eerder opgemerkt, stelt dat de vooruitgang in het onderwijs, of de 'kwaliteit' van arbeid in het algemeen, slechts een kleine rol speelde in de groei van de totale factor productiviteit tussen de jaren 1929 en 1941.

Om het feitelijke effect van de aanzienlijke investeringen in scholing op de Amerikaanse economie vast te stellen, maak ik gebruik van een methode ontwikkeld door Dale Jorgenson en Zvi Griliches. De belangrijkste vernieuwing in deze methodiek is dat zij de traditionele maatstaf van arbeid corrigeren voor verbeteringen in kwaliteit. Ze maken onderscheid tussen verschillende factoren die het productiviteitspotentieel van de gemiddelde werknemer kunnen beïnvloeden (b.v. opleidingsniveau, maar ook werkervaring en sekse) en wegen deze aan de hand van informatie over de reële beloningen. In een boekhoudkundig kader, ook wel *growth accounting* genoemd, kan de productiegroei als gevolg van beter opgeleide en getrainde werknemers nu worden toegeschreven aan de groei van arbeidsinput in plaats van de onverklaarde totale factorproductiviteit.

In tegenstelling tot eerdere studies maak ik een schatting van de verandering van de kwaliteit van arbeid op het industrie-niveau, wat mij in staat stelt om de ontwikkeling van menselijk kapitaal in kaart te brengen voor niet alleen de gehele Amerikaanse beroepsbevolking, maar ook separaat voor afzonderlijke sectoren en industrieën. Ik kom tot de conclusie dat er sprake was van een gestage toename van arbeidskwaliteit in de decennia tussen 1900 en 1950, met een gemiddelde groei van iets meer dan 0,7 procent op jaarbasis. In vergelijking met zowel recentere decennia als de ontwikkeling van het menselijk kapitaal in andere landen was dit een relatief snelle stijging. De groei was voornamelijk het gevolg van een algemene verschuiving van werkgelegenheid van de minder productieve agrarische sector naar hoogproductieve sectoren (diensten), in combinatie met een algemene stijging van het opleidingsniveau van de beroepsbevolking.

Deze nieuwe schatting komt overeen met de door Goldin en Katz geobserveerde stijging van het gemiddelde Amerikaanse opleidingsniveau. Derhalve concludeer ik dat de bewering van Field, dat de verandering in de arbeidskwaliteit tijdens de depressiejaren slechts een kleine rol speelde in de snelle groei van (arbeids)productiviteit, geen stand houdt. Hij baseerde zijn berekeningen op het werk van John Kendrick, die het groeipercentage voor de periode 1900–1950 half zo hoog inschat als mijn meest conservatieve schatting. Daarnaast stelt Kendrick dat er weinig tot geen groei in arbeidskwaliteit plaatsvond tussen 1920 en 1940, terwijl mijn cijfers een continue en sterke groei laten zien gedurende het gehele interbellum. Mijn nieuwe schattingen illustreren dat de kwaliteit van de Amerikaanse beroepsbevolking ook bleef verbeteren tijdens de depressiejaren, met tot gevolg de snelle technologische vooruitgang en de omvangrijke modernisering van de jaren dertig en daarna.

Alhoewel de jaren dertig ontegenzeggelijk zijn gehavend door de hoge werkloosheid, massale migratie en diepgaande sociale en culturele veranderingen, was dit decennium verre van somber in termen van technologische vernieuwingen en organisatorische veranderingen. De vooruitgang in producten en materialen, verbeteringen in de opzet van fabrieken, management en menselijk kapitaal en de opkomst van nieuwe productietechnieken plaatste zowel de Amerikaanse als de Britse economie in een positie die snelle groei en ontwikkeling mogelijk maakte. In het licht van deze ontwikkelingen is de term “Gloomy Thirties” voor dit decennium dan ook te somber. Gelet op de grote technologische vooruitgang en de uitgebreide modernisering van de productieprocessen zou dit tumultueuze decennium met evenveel recht kunnen worden getypeerd als de “Roaring Thirties”. Dit is dan ook de titel die ik aan mijn proefschrift gegeven heb.